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EXPLORATION OF MUMMY CAVES IN THE ALEUTIAN ISLANDS

PART I. PREVIOUS KNOWLEDGE OF SUCH CAVES. ORIGINAL EXPLORATIONS

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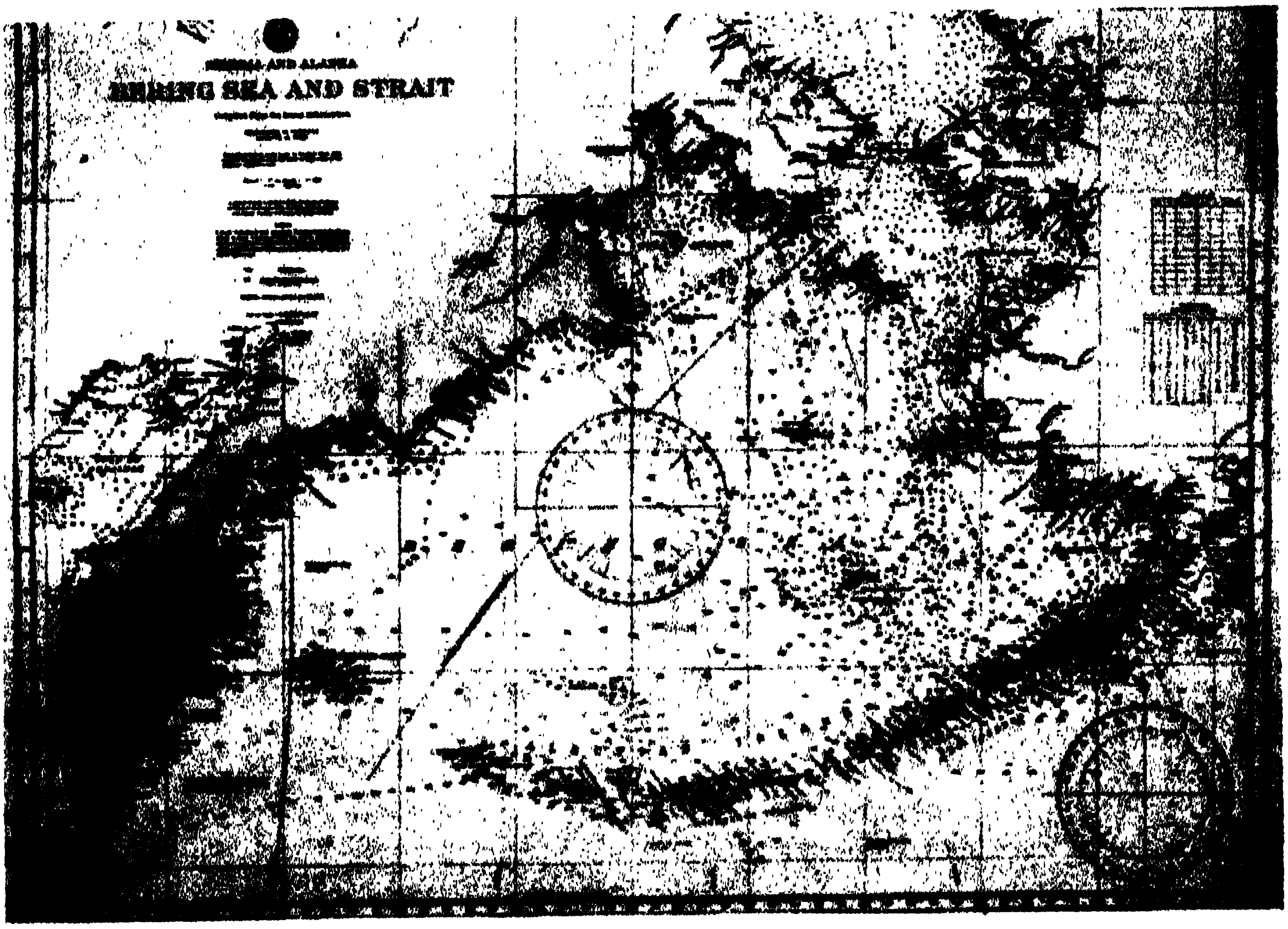
THE subject of human "mummies" has always had a peculiar attraction. This mainly because it is odd to see bodies hundreds or even thousands of years dead, yet still whole and showing more or less of the original features of their owners. But also because the subject appeals to mysticism, and has the halo of dynastic Egypt, where artificial mummification originated, was eventually applied to the bodies of all the rulers, the mighty and the rich, and reached the highest developments.

The practice of mummification resulted in general from a belief in future life. In the Old World it apparently remained limited essentially to Egypt, though it reached to some extent the Canary Islands. In later times it was practiced in a measure, and quite independently probably, among the Papuans of the Torres Straits; and with outstanding personages may have been attempted, more or less, elsewhere. It had not become habitual, so far as known, in any part of Africa outside of Egypt, in Europe or in Asia. But it developed in two wide apart regions in America—in Peru with the neighboring territories, and among the Gulf populations of Alaska, more particularly in the Aleutian Islands.

How the practice started in these two American regions is not known. It may have originated there from the same causes as in Egypt, and in each area independently; it may have developed in Peru and been somehow transmitted to Alaska, though this seems far-fetched—as would be the supposition that it reached Peru from Alaska. It would be hard to connect it in either region with Egypt—yet such a connection may not have been wholly impossible. At this date, unless some new evidence should come from Siberia, these problems are probably incapable of solution.

Mummification in both Egypt and in America was of two kinds, the natural and the artificial. Natural mummification of bodies—which in all probability suggested eventually the assisted or artificial practices—took and now takes place in all regions and places where there is a lack of moisture. The deserts, dry caves, dry tombs, are its locations. Many natural mummies exist in the desert sands in Egypt, and many also were found in dry caves or rock-shelters in America, in parts of Peru, Mexico, the Southwest and



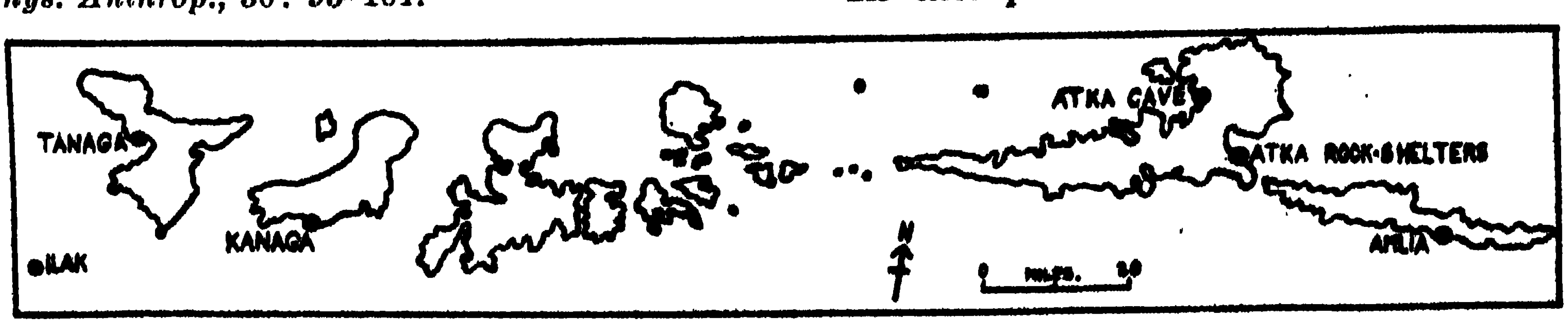
THE BERING SEA AND STRAIT
SHOWING LOCATION OF ALEUTIAN ISLANDS.

other regions. Such American mummies were or are mostly without wrappings, and are more or less damaged by insects, rodents and the elements; but a few of those found have shown remarkable preservation, so much so that fairly successful efforts were possible at a restoration, through certain fluids, of an approach to the original features of the heads, hands and feet of such mummies.[1] They were, and still are, as a rule, found in a sitting posture, with the arms and knees drawn up to the chest and the head bending forward.

[1] See: H. H. Wilder, *Am. Anthrop.*, 6: 1–17; also J. Gillman, *Am. Jour. Phys. Anthrop.*, 18: 363–69 and M. F. Ashley-Montagu, *Am. Jour. Phys. Anthrop.*, 30: 95–101.

The *artificial* mummies, both in Egypt and in America, had in common the initial removal of the internal organs; but the subsequent treatment of the body differed. The Egyptians embalmed the body by various balsams, pitch and other materials, and then artfully bandaged the body; the Americans used essentially air drying, and in some cases stuffing with dry moss or grass, after which, without pitch, balsams (so far as known) or bandages, they dressed the body in the best available clothes and made up the whole—with cotton in Peru, with mats and skins in the Far Northwest—into a bundle.

In this place we will deal only with



LOCATIONS OF BURIAL CAVES AND ROCK-SHELTERS,
ANDREIANOV ISLANDS, ALEUTIAN CHAIN.

UNALASKA, IN THE EARLIEST PART OF THE NINETEENTH CENTURY
(AFTER A DESIGN BY CHORIS, 1822).

artificial mummification in the Far Northwest and more especially with that in the Aleutian Islands.

That the practice of artificial mummification of the dead once existed in these islands was repeatedly reported by the Aleuts to the Russians.

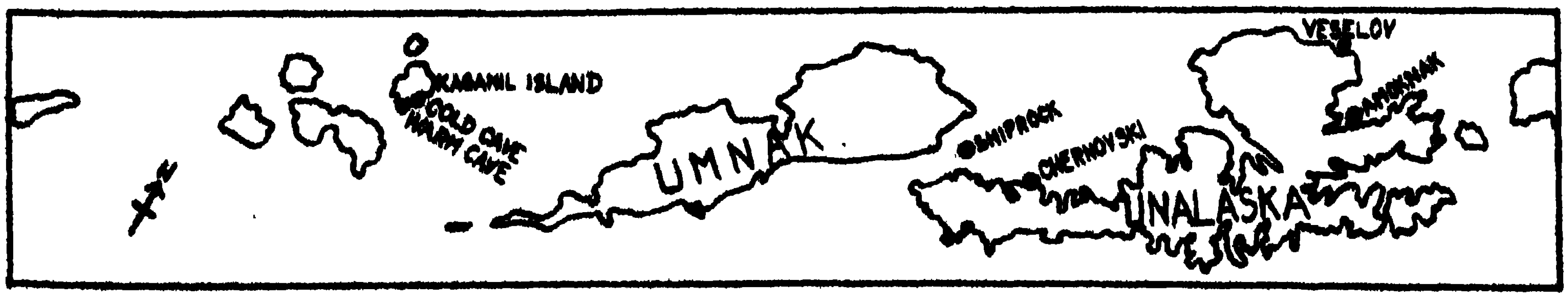
The first account of it is found in Martin Sauer's report (Lond., 1802) of Commander Billings' visit (around 1790) to the islands. Speaking of burials among the Aleuts of the Unalaska District, Sauer, who was the secretary of Billings and interpreter, says (p. 161):

> They pay respect to the memory of the dead; for they embalm the bodies of the men with dried moss and grass; bury them in their best attire, in a sitting posture, in a strong box, with their darts and implements; and decorate the tomb with various coloured mats, embroidery and paintings. With women, indeed, they use less ceremony. A mother will keep a dead child thus embalmed in their hut for some months, constantly wiping it dry; and they bury it when it begins to smell, or when they get reconciled to parting with it.

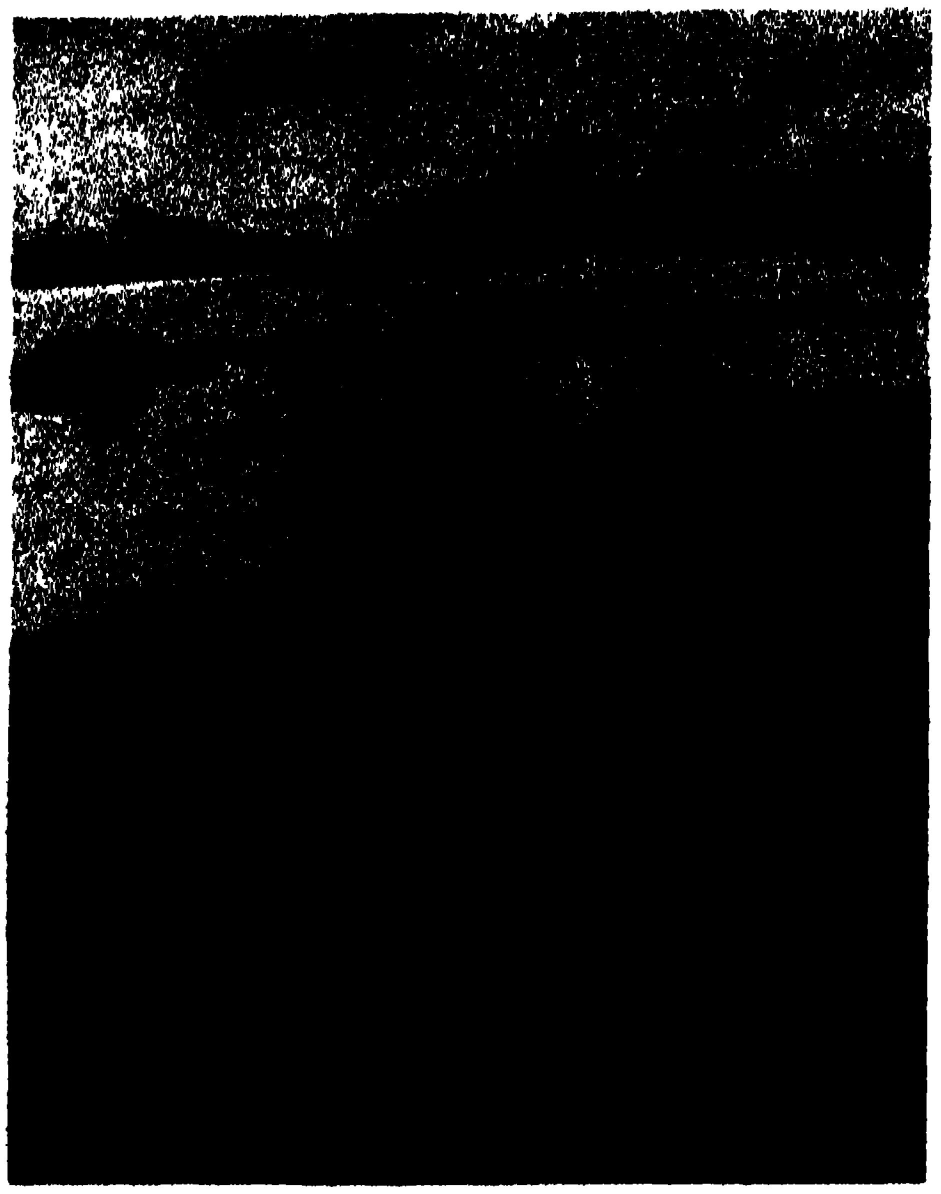
In Saryčev's account of the same expedition (Lond., 1806–7, II, 77) the same subject is briefly noted thus: "The entrails are taken out of the corpse; which is stuffed with hay."

A somewhat more circumstantial account of the practice is given, in 1840, by Bishop Veniaminov, in his classic and rare work on the Unalaskan Aleuts, among whom he spent ten years of his life[2] as their priest and friend. He says: (II, 80–81):

[2] I. Veniaminov "Zapiski ob ostrovach Unalaškinskago Otdiela." 3 vs. (in 2), 8°, Acad. Sc., St. Petersb'g., 1840.



LOCATIONS OF BURIAL CAVES AND ROCK-SHELTERS,
FOX ISLANDS, ALEUTIAN CHAIN.



A FINE, UNTOUCHED OLD SITE OF LITTLE KISKA

IN THE ALEUTIAN ISLANDS. THERE ARE LITERALLY HUNDREDS OF SUCH UNTOUCHED OLD SITES OF HUMAN HABITATION IN THE ISLANDS WHICH CAN BE READILY DISCERNED BY MEANS OF THEIR RICHER AND DIFFERENT VEGETATION.

In former times, in case of every Aleut who died, his relatives grieved over him for 40 days, and did not bring out his body from the house for 15 days. Several days after death they *embalmed* the body, *i.e.*, they opened it, and extracting all the internal organs, stuffed the trunk with dry grass and sewed it up. After that they dressed the body in his best and most favored garment, and swaddling it like a baby, they placed it in a framed skin "cradle" which they hung in the place where the individual died and where they kept it for another 15 days. . . . Bodies of the poorer and of the serfs they lay in caves. However, it appears that sometimes they lay in the caves also the rich, as may be witnessed even now according to some indications.

And further (III, 11):

From the body of a man who died at sea, in order that he should not decay rapidly, they nearly always removed the internal organs and buried them separately.

The natives told Veniaminov of two caves with "mummies," one on the Kagamil and one on the Tanginak, or Korabl (now Shiprock), islands. Kagamil, he says (I, 135–36):

is further remarkable for the fact that on its western side, in a cave, there may up to now [1835] be seen the dead bodies of some people hanging in swings. By them are found all their goods: mats, parkis, otter skins, weapons, kind of bags, etc.; and they say that the bodies as well as everything that is with them are perfectly well preserved, but that no one must touch them, because, they say, those who touched even the weapons became afflicted with open sores all over the body, and after long suffering died.

And (II, 132):

The Aleuts tell that some of the bodies to be found even now in caves on one of the Four-Mountain-Group Islands, were already in the earliest times of the Aleuts in the same condition as they are now. They lie one by the other, dressed in fur parki, their beard and hair brown or reddish, the skin on the body blackish. And it was from these bodies that the hunters endeavored to cut parts of the flesh and especially some part of the hand and of the small finger, or at least a part of the garments, [for good luck in hunting]. But he who had such things, even though really more fortunate in hunting, nearly always died early and with a horrible death—beginning to decay already in his best years.

As to the Korabl Island (Shiprock), Veniaminov says:

On the south side of this little island there is a cave in which there are the bodies of the old-time (unchristened) Aleuts, in sitting posture, and which even now are free from decay.

Going to such caves was forbidden to the young. According to the same author (II, 122, ftn.):

For a long time, even after the acceptance of Christianity, the old men and women prohibited the younger from going to forbidden places, but now there are none of such forbidden spots, with the exception of the caves where are found the bones of dead former Aleuts.

A. L. Pinart, a French archeologist, visited some of the eastern Aleutian Islands in 1871 and found there two burial caves, one on Unga and the other on Amoknak. He made a remarkable collection of carved and painted wooden

objects in the Unga cave,[3] but saw no whole mummies there. In the Amoknak cave there also were no whole bodies anymore, but there were remains of the same. Pinart called this cave to the attention of Dr. Dall and in 1872 and 1873 the latter explored it. In his article on "Alaskan Mummies"[4] Dall refers to these and other such caves as follows:

Among the localities which have been visited personally by the writer, are caves in Unga, one of the Shumagin Island, and others on the islands of Amaknak and Atka, further west. In all of these the remains of mummies existed: but the effect of falling rock from above, and great age, had in all the caves except that of Unga, destroyed the more perishable portions of the remains, and in the latter place only fragments remained. Many stories, however, came to hand in relation to a cave on the "Islands of the Four-Mountains" west of Unalashka, where a large number of perfectly preserved specimens were said to exist.

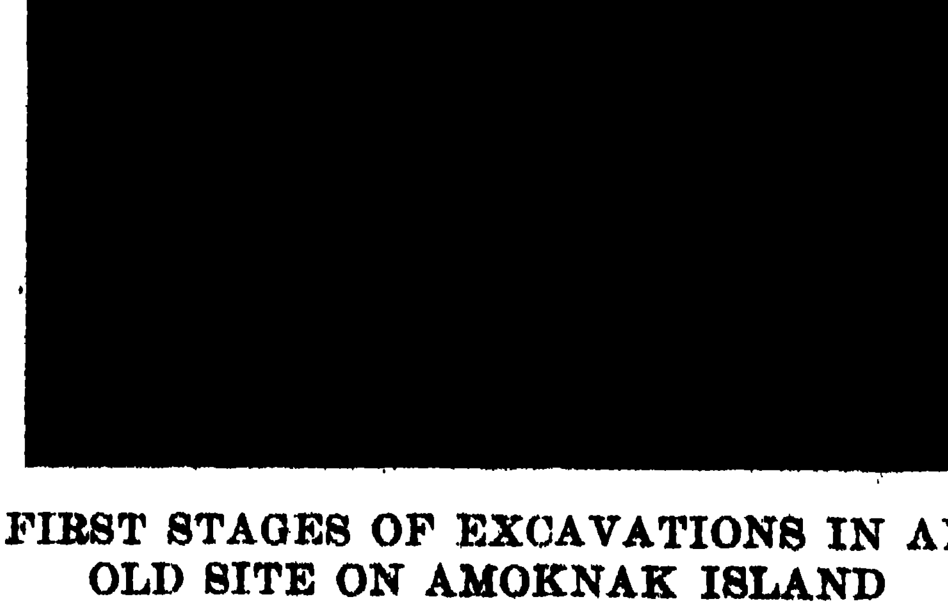
When in the vicinity, in 1873, we were unable to land and test the truth of this history, on account of bad weather and the absence of any harbors.

In 1874, however, Captain E. Hennig, of the Alaska Commercial Company:

being employed in removing some hunters from the island of the Four Mountains, was enabled, after seven unsuccessful attempts, to land at the base of the cliff, where the fallen rocks form a kind of cave, and was directed by the natives to the exact spot. Here he obtained twelve mummies, in good condition, besides several skulls of those which, being laid near the entrance of the cave, had become injured by the weather. There was also a moderate number of carvings and implements found, though some natives, less superstitious than the rest, had appropriated a quantity of weapons (reported to have once been there) for use in hunting. The island being volcanic and, in fact, still active, the soil is still warm, and the atmosphere of the cave was quite hot, which accounts for the extremely good preservation of the remains. Most of the bodies were simply eviscerated, stuffed with grass, dried, wrapped in furs and grass matting, and then secured in a waterproof covering of seal-hide. Two or three had much more pains bestowed upon them, and were of course of much more interest.[5]

To this in 1875[6] Dall adds:

Most of the mummies [from the Kagamil cave] were wrapped up in skins or matting as previously described, but a few were encased in frames covered with sealskin or fine matting, and still retaining the sinew grummets by which they were suspended. These cases were five-sided, the two lateral ends subtriangular; the back, bottom and sloping top, rectangular, like a buggy top turned upside down. With them were found some wooden dishes, a few small ivory carvings and toys, a number of other implements, but no weapons except a few lance or dart heads of stone. Two or three women's work bags with their accumulated scraps of embroidery, sinew, tools and raw materials were among the collection. . . . It contained thirteen complete mummies, from infants to adults, two of which were retained in California; and two detached skulls. None of the material showed



FIRST STAGES OF EXCAVATIONS IN AN OLD SITE ON AMOKNAK ISLAND

THIS SITE, WHICH IS STILL FAR FROM EXHAUSTED, HAS GIVEN US MANY HUNDREDS OF INTERESTING SPECIMENS, INCLUDING SOME BURIALS. IT BELONGED ORIGINALLY TO THE PRE-ALEUTS.

[3] "Catalogue des collection rapportée de l'Amérique Russe" par Alphonse Pinart, Exposées dans le Musée d'Historie Naturelle de Paris, 1872, Paris; also, "La caverne d'Aknañh île d'Ounga (archipel Shumagin, Alaska), Paris (E. Leroux), 1875.

[4] *Am. Naturalist*, 9: 436, 1875.

[5] "Notes on Some Aleut Mummies," *Proc. Calif. Acad. Sci.*, 5: 399–400, 1873.

[6] *Amer. Naturalist*, Aug., 1875; reprint in the Indian Miscellany, Albany, 1877, 344–351.

THE AUTHOR, WITH AN OFFICER OF THE S.S. *TALAPOOSA*
(ORDWAY, 1936).

any signs of civilized influences, all was of indigenous production, either native to the islands, or derived from internative traffic or drift wood. The latter comprised a few pieces of pine resin and bark, birch bark and fragments of reindeer skin from Alaska peninsula.

Regarding the mummies of the children, Dr. Dall says:[7]

The case [of these] was sometimes cradle-shaped, especially when the body was that of an infant. On these occasions it was often of wood, ornamented as highly as their resources would allow, painted with red, blue or green native pigments, carved, adorned with pendants of carved wood and suspended by braided cords of whale sinew from two wooden hoops, like the arches used in the game of croquet. The innermost wrappings of infants was usually of the finest fur, and from the invariable condition of the contained remains it is probable that the bodies were encased without undergoing the process previously described. The practice of suspension was undoubtedly due to a desire to avoid the dampness induced by contact with the soil.

As to the finds themselves, Dall says:[8]

The mummies of real interest were few in number. The most conspicuous was that of the old chief. I am informed that this body was enveloped in furs, dressed in the usual native attire, and furnished with a sort of wooden armor, formerly worn by the Aleuts. The whole was placed in a sort of a basket, in a sitting posture, and carefully covered with water-proof skins, secured by lines made of sinew, either braided or made into what sailors call "square sonnit." This line, together with a net made of sinew, in which another of the bodies was secured, were very finely made, and nearly as perfect and strong as when first placed there. The matting, made of prepared grass, was exceedingly fine, in most cases far superior in finish and delicacy to any now made in the islands. One of the smaller mummies, in a triangular-shaped bundle or basket, had a pattern of a Maltese cross worked into a stripe of another color; this was quite fresh, and the grass still retained its red and yellow tinge. The largest basket has a wooden arrangement fastened with bone buttons, forming a broad hoop, which served it for a base. Most of the more carefully preserved specimens had been once suspended in the air by handles or cords attached to their envelopes.

The other articles found in the cave were stone knives and other implements, and a few carv-

[7] *Am. Naturalist*, 9: 436.

[8] *Proc. Calif. Acad. Sci.*, 5: 399–400, 1873.

ings, one of which was supposed by the finder to be an idol, but this is probably an error. A child's boot of native make was found in the cave, with the fur perfectly preserved, and in it was a little ivory image of a sea-otter. A number of other bone and ivory toys or trinkets were also found.

The only other worker in Alaska who gave direct attention to the Aleutian mummies and burial caves was Dr. Jochelson. The results of his inquiries and observations are published in his excellent "Archeological Investigations in the Aleutian Islands" (4 to, Carnegie Inst., Wash., 1925). After a discussion of their behaviors with the dead, Dr. Jochelson says (p. 42):

The Aleut achieved the art of mummifying the bodies of their dead, which made possible their preservation and postponed the time for final disposal. It may be contended that mummification could not succeed in the cold and wet climate of the Aleutian Islands, but such is not the case. The Aleut used no drugs for embalming, but proceeded as follows: An incision was made in the perineum and the intestines removed through the pelvis, or an incision was made over the stomach for that purpose. The intestines were carefully cleaned, all fatty substances removed, and then stuffed with dry scented grasses. Then the corpse was arrayed in its best clothing, over which a kamleika (water-proof shirt made of the guts of sea mammals) was drawn. Then it was arranged in a squatting position with knees drawn up to the chin. Wrapped in closely plaited grass-mats and seal or sea-lion skins taken from the cover of the dead man's boat, the corpse was lashed into a compact bundle with thongs of sea-weed ropes. Then the whole package was again wrapped in a net made of sea-lion sinews.

To which Dr. Jochelson adds (pp. 44–49):

An old Aleut informed us that not all Aleuts were embalmed, this being the privilege of noted hunters, especially whale-hunters. Corpses of honored people and of the families of chiefs were also mummified (p. 44). Two types of caves were used as burial places: one with deep grotto-like passages with a large opening, the other in the form of small hollows in the rock. Mummified corpses of distinguished people were hung up chiefly in the bottom of the grotto-like caves, while in the small caves, which evidently were regarded as village cemeteries, all the less distinguished dead were placed (p. 45). Small cave cemeteries of the second type, sack-shaped hollows in the rock, were found on Atka and Amaknax. Two such caves were discovered on Atka, near the Atxalax village site. Evidently both caves had served as burial places for the inhabitants of the village (p. 46). In addition to the large grotto-like caves in which the Aleut suspended their mummified dead and the smaller caves which served as village cemeteries, the Aleuts used compartments in their underground dwellings or special lodges for the disposal of their dead. For the latter two methods the bodies were prepared as for cave burial (p. 49).

Further on (p. 123), Dr. Jochelson mentions a burial cave on each of the islands of Ilak, Samalga and Ulagan, but those he did not examine; and he failed in his effort to reach the cave on Kagamil.[9]

The practice of partial preservation or mummification of some of the dead was not limited to the Aleutian Islands. It extended also to the Peninsula (or parts of it), to the Kadiak Island, to the islands of the Prince William Sound and to those of southeastern Alaska and British Columbia. Regarding the Peninsula and Kadiak Island, Dall,[10] after earlier sources, tells us as follows:

The practice of preserving the bodies of the dead was in vogue among the inhabitants of the Aleutian Islands and the Kadiak archipelago at the time of their discovery, and probably had been the custom among them for centuries. The Kaniagmut Eskimo, inhabiting the peninsula of Aliaska, the Kadiak archipelago and the islands south of the peninsula, added, to the practice of mummifying the dead, the custom of preparing the remains in some cases in natural attitudes, dressing them in elaborately

[9] Regarding this cave both Dall and Jochelson give a native tradition of a burial there, shortly before the Russians came, of a local chief with his family; and Dall believed that their mummies were among those taken out by Captain Hennig, which is possible, though doubtful. See later account of the cave.

[10] *Am. Naturalist*, 9: 434 et seq.; repr. in The Indian Miscellany, Albany, 1877, 344 et seq. (1881). See also his "On The Remains of Later Prehistoric Man Obtained from Caves in the Catherina Archipelago, Alaska Territory, and Especially from the Caves of the Aleutian Islands," Smithsonian Contribution to Knowledge, Washington, 1878.

SMOKING BEACH IN FRONT OF WARM CAVE ON KAGAMIL ISLAND IN 1936

THE WHOLE ISLAND IS A VOLCANO AND IS EVIDENTLY STILL ALIVE IN ITS INTERIOR. THE SMOKE AMONG THE BOULDERS ON THE BEACH RISES FROM BOILING HOT LITTLE STREAMS THAT ISSUE FROM THE CLIFFS.

ornamented clothing, sometimes with wooden armor, and carved masks. They were represented, women as serving or nursing children; hunters in the chase, seated in canoes and transfixing wooden effigies of the animals they were wont to pursue; old men beating the tambourine, their recognized employment at all native festivals. During the mystic dances, formerly practiced before a stuffed image, the dancers wore a wooden mask which had no eye-holes, but was so arranged that they could only see the ground at their feet. At a certain moment they thought that a spirit, whom it was death or disaster to look upon, descended into the idol. Hence the protection of the mask. A similar idea led them to protect the dead man, gone to the haunts of spirits, from the sight of the supernatural visitor. After their dances were over the temporary idol was destroyed. . . . In Kadiak still another custom was in vogue. Those natives who hunted the whale formed a peculiar caste by themselves. Although highly respected for their prowess and the important contributions they made to the food of the community, they were considered during the hunting season as unclean. The profession descended in families and the bodies of successful hunters were preserved with religious care by their successors. These mummies were hidden away in caves only known to the possessors. A certain luck was supposed to attend the possession of bodies of successful hunters. Hence one whaler, if he could, would steal the mummies belonging to another, and secrete them in his own cave, in order to obtain success in his profession.

As to Prince William Sound, information is meager, but there is still a definite remembrance among the old timers of the region of "mummy caves" on at least one of the islands of this group. Farther east, along the Alaska Gulf and northwest coasts, carved mortuary boxes with desiccated remains, in one case a whole child mummy (now in the Museum at Seattle) have been found in the forests on some of the islands, but there is no recorded tradition about the practice of preserving the dead in these regions.

Original Explorations

The writer's original exploration for mummies was limited to the Aleutian Islands, and was based on the old Russian as well as Dall's and Jochelson's information, supplemented with some valuable hints from the old natives and other sources. The search began towards the end of the 1936 season, and continued through those of 1937 and 1938. Thanks to the U. S. Coast Guard it became possible to find a series of these caves, with results that collectively proved not only of first importance to physical anthropology, but from the cultural side amounted to a veritable resurrection of perishable objects that could be found in no other manner.

The search for the caves proved both exciting and dangerous. It will be best to give the details in the form of the original notes, for nothing else could do the work such justice.

1936–July 28. The fine Coast Guard boat "Chelan," Captain L. V. Kielhorn, is taking us off from the island of Kiska, where we have been excavating for several weeks. Calm to-day, but very foggy —as most of the time here. Can not even see the Little Kiska where we worked part of the time in a fine old site, and had some rare experiences. The Captain promises to stop in the bay at Kagamil Island where we are to find and explore the mummy cave that both Dall and Jochelson tried in vain to reach, and that has recently for our benefit been located by the "Brown Bear" of the Biological Survey, which kindly came to Kiska to tell us about it, and brought a mummy with a couple of bags of bones from the cave as evidence. The information as to the locality of the cavern is still somewhat indefinite, for the "Brown Bear" could stay only a short time due to weather conditions; but there is said to be a good landmark some distance beyond the cave in the nature of a steam jet issuing from the mountain.

July 29. Up early, for we are approaching the Four-Mountain-Group. But everything is so foggy that we can not even see a trace of the islands, though there are some huge volcanoes. Moreover the waters about the group are not

EXCAVATIONS IN THE WARM CAVE OF KAGAMIL ISLAND IN 1936
SINCE IT WAS IMPOSSIBLE, DUE TO LACK OF SPACE, TO USE ANY TOOLS, IT WAS NECESSARY TO DIG BADGER-LIKE. FORTUNATELY THE DEPOSITS WERE NOT HARD, BUT THE SALTY DUST AND THE HEAT AT LOWER LEVELS WERE RATHER TRYING.

yet well charted, so that the Captain feels unable to approach closely. With a great disappointment we must eventually leave, without getting even a glimpse of our Island. . . .

July 31–Aug. 3. Excavating on Amoknak Island.

August 4, 8:00 A.M. A message from Captain Dempwolf to meet him this A.M. and also Captain Kielhorn of the "Chelan" at Unalaska. Conference on the "Chelan" at 10, barometer rising, arrange to go once more to Kagamil at 2 P.M. Hasten back, recall companions—all excited and eager. Have lunch, at 1:20 a boat for us, at 1:40 all on the "Chelan," at 2 off for Kagamil. Weather and sea fairly good, though a "swell." Stop at Kashega, little native village of a few straggling Aleut dwellings, to discharge a sick woman.

August 5, 4:00 A.M. Dense fog—terrible. 6:30 A.M. Fog lifts as if by enchantment, and there, not far on the horizon before us, is Kagamil. Carefully find anchorage, in a shallow cove, have breakfast, and at 8:30 off in a dory for the "mummy cave" reported by the "Brown Bear."

After about an hour find the jet of steam—about seven miles from the ship; and soon locate also the crevice of the cave. The jet issues from a barren cliff a few hundred yards to the left of the cave, and other steam cloudlets rise from bubbling hot springs among boulders above and in rocky beach.

Cave well above reach of storms and spray. Its orifice a cleft in the volcanic rocks. Approach difficult, but soon mastered. Inside, cave low, a huge fallen slab in middle—some skulls, debris of skeletons, deposit of white salt-like substance over all. Two fairly large recesses of the cleft filled with debris of mummies left by foxes—shreds of matting, bones,

parts of skeletons—all on or in white deposit. Also some old driftwood and hand-hewn planks, evidently remains of crude platforms on which mummies had rested. In one of the recesses the white salt (which also encrusts, somewhat stalactite-like, much of the ceiling)—forms already a solid covering of some of the remains, so hard in places it can not be broken with a pick.

Space within cave limited, in most of it one can not stand up, in none of it can use shovels; must work with hands like badgers, but luckily much of deposit proves not hard. But there is soon a great deal of dust; also the recesses are dark, and there are but a couple of small searchlights to help along. As the salt[11] deposit is penetrated into, there appears mummy after mummy, in different states of preservation—male, female and especially children. Small children in unique baskets, woven, plaited or skin. Some loose specimens of stone and bone; grass bags with objects—no time to see; a huge whale shoulder blade with two apertures for handling; and two entire kayaks, though frame work and shreds of skin covering left only. My four boys (students) as well as myself work strenuously, to the limit, to secure as much as possible, for at any moment it may get rough or foggy outside and we be called off. The inside is very dusty, and the dust irritates, but do not mind. Wonderful riches. An officer and a couple of men from boat helping effectively—more can not get in. From time to time one or

[11] On analysis, later found to be actually mainly common salt.

THE WARM MUMMY CAVE ON KAGAMIL ISLAND

AS FOUND ON FIRST ENTERING IT IN 1936. THE CAVE WAS SO FILLED WITH SALTY DEBRIS AND MUMMIES THAT IT WAS AT FIRST IMPOSSIBLE TO STAND UP IN IT. THE REMAINS ON THE TOP HAD BEEN DESPOILED BY STARVING FOXES, BUT THE MUMMIES LAY IN PLACES SEVERAL DEEP. THE WHOLE CAVE WAS DRY AND WARM, HEATED BY THE HOT LAVA SOMEWHERE UNDERNEATH.

another must get out a little to get a few breaths of clean air.

Near 1:00 a sandwich outside the hole—eight minutes—then work again to the limit till 4:00 P.M., then must cease, to enable men to get back to boat for supper. Most fortunately weather has kept fairly good and no fog closed in. Load everything into a large dory which takes it to the ship—have so much the boat has to make two trips—and leave finally near 5:00. Main things secured, but all not yet exhausted. Yet no possibility of staying any longer.

The cave was dry and warm. As we dug down, particularly in the recesses, the deposits and even the air became steadily warmer, until, on the right, as the arm reached for about two thirds of its length, the deposits became almost too warm to work in.

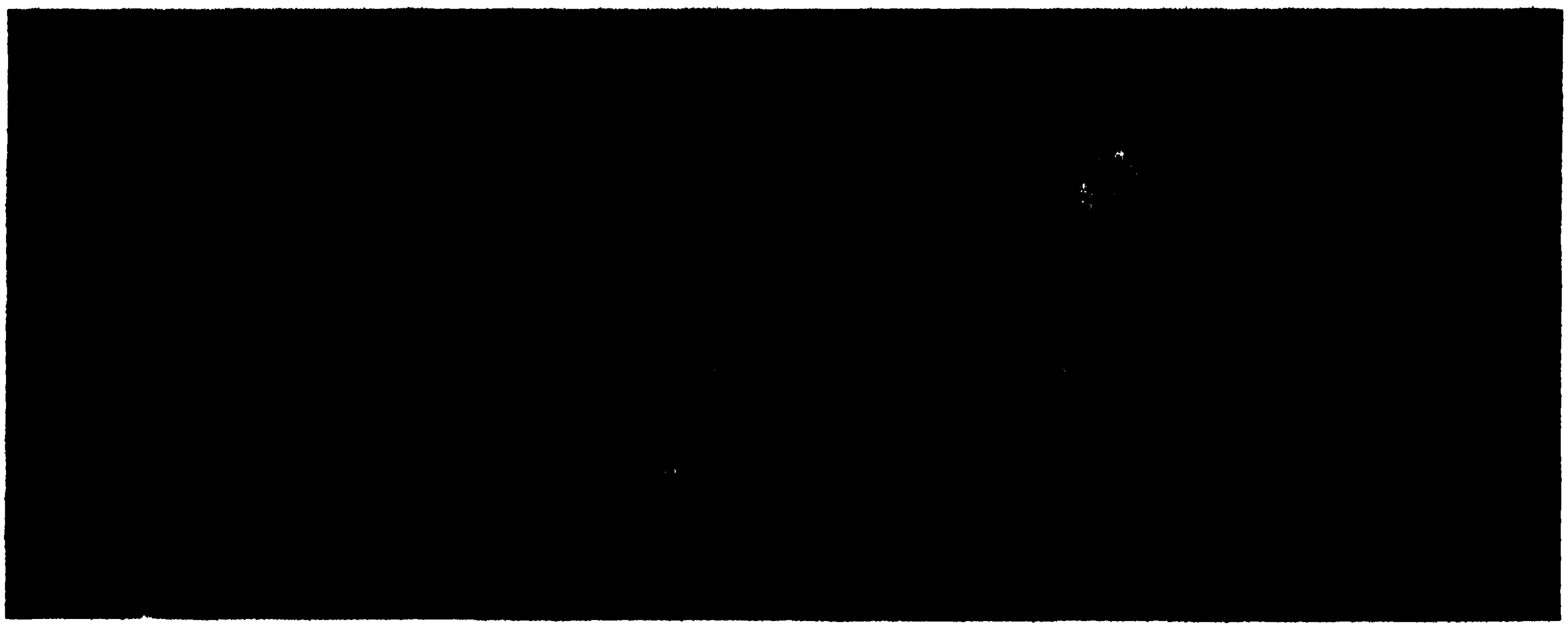
Secured in all over 50 mummies, though most children; and about 30 additional skulls, besides numerous miscellaneous bones. In addition, a great quantity of partly damaged, partly still good, remarkably made and decorated matting; and there were a mass of shreds of fur (sea-otter), feather garments, feathers, dried-up birds or bird wings, shreds of various ingeniously made cords, many pieces of worked wood from kayaks, or armor, etc., etc.

When we reach the "Chelan" find all excited. The sacks of mummies, etc., make a great pile on deck forward of bridge, where the whole, for safety, at the Captain's order, is covered and secured under canvas.

On way home I have spotted in the crags of the shore an opening of what may be another good cave, which my

THE COLD MUMMY CAVE ON KAGAMIL ISLAND

THE PHOTOGRAPH SHOWS THE EXCEEDINGLY ROUGH NATURE OF THE OLD LAVAS IN WHICH THE CAVE WAS FORMED. IT ALSO GIVES SOME IDEA OF THE DIFFICULTIES OF APPROACH AND ESPECIALLY OF CARRYING THE COLLECTIONS OVER THE TOP OF THE CLIFFS.



HEAD OF A MUMMY, WARM CAVE, KAGAMIL ISLAND
REMARKABLY PRESERVED MONGOLOID PHYSIOGNOMY.

whole party craves to visit tomorrow. The Captain would like to leave—afraid of bad weather—but Commander Dempwolf, the head of the Alaska station, persuades him to stay.

Rich day. Warm shower, supper. No weariness. Of the officers and men of the boat every one would like to go with us tomorrow.

Thursday—Aug. 6. Up before 6. Sky fairly good, but a 30-mile gale from across the depression in the island, and water very rough. All our party gloomy, and not much appetite for breakfast. At one time the wind is so strong there is some fear the ship will drag, and probably have to leave. But about 9:00 things begin to moderate. At 9:30 gale over, and though still considerable waves we are able to leave with the large dory and a surf boat. No possibility of landing anywhere near second cave, so proceed to a partly sheltered cove about half a mile away. The coast here is nothing but huge boulders piled one upon another, with pools and leads of heaving water between. Landing even from surf boat difficult and risky, but somehow manage. Then up a very steep slope with high grass, over rough volcanic upland, then down another very steep pass into a hollow filled with rank vegetation and huge boulders among which there are deep unseen crevices, and finally on the bare big boulders of the beach, from which can be seen the opening of the new cave. Also along the route and especially in the hollows many gnats, and biting, though not as poisonous as at Uyak.

Climb over rocks into the cave, which is more spacious than the first, but cold, damp and dripping from the ceiling; also with barely light enough to see what confronts us. What we gradually perceive is desolate, as well as rich. Skulls and especially bones protrude everywhere from debris of skins, furs, mats and driftwood. The cave had contained several tiers of mummies laid on driftwood scaffolding, which in the course of time has collapsed. The cave has evidently not been visited by white man, but everything has been damaged or destroyed by foxes. For some years now traders have placed foxes on the island, left them there without food, and the animals lived partly on the mummies, and destroyed, even shredded, most of the coverings and mats. They even devoured or damaged, more or less, such bones as they could chew. The whole presented a devastation.

But there was no time to spare. At any moment there might set in another storm, or fog, and we will be called away.

HEAD OF A MUMMY, FROM KAGAMIL
THERE WAS A PERFORATION IN THE LOWER OUTER PART OF THE LEFT EAR, IN WHICH THERE IS A COLORED FEATHER FOR DECORATION.

So once more we set to work against time, with the help of Dr. Bingham, the ship surgeon, together with one of the officers, and one man from the ship. By 3:00

MOVING COLLECTIONS FROM THE COLD CAVE ON KAGAMIL ISLAND IN 1936
OVER DIFFICULT TERRAIN. RELAYS PROVIDED THE ONLY POSSIBILITY OF TRANSPORTING THE MATERIAL. EVEN IN THIS WAY THE HALF-MILE TRANSFER TRIP TOOK NEAR TWO HOURS.

P.M. we had filled 24 sacks, besides which there was one large mummy still in a fair state of preservation, a heavy bag with cameras, torches, etc. The foxes, we found, had their holes and lairs under everything. There being much wood in the cave and the air being damp and cool, we tried to make fire, with the result that we were almost driven out by acrid smoke but could get no real flame.

Aside of the skulls, bones and other

SHRUNKEN JIVARO HEAD FROM ECUADOR
SHOWING THE SAME TYPE OF DECORATION (FEATHER IN THE EAR). THIS IS ONE OF THE MANY EXAMPLES THAT RELATE REMOTE AMERICAN CULTURES WITH ONE ANOTHER.

remnants of mummies, there were a number of parts of war shields, several beautifully carved spoons, three unique inlaid ivory labrets, a shred of especially artful matting, a stone lamp, a few slate knives and whetstones, and many remnants of decorated mats, native cords and other articles.

Our sandwiches, and coffee, were left in the dory—but there would have been

no time for them anyway. At 3:00 P.M. and before it was possible entirely to finish with the cave, word came from the outside that the weather was failing again and that we must hurry back to the boat. As there was no possibility of even the surf boat coming near to where we were, it was necessary to retrace our steps over the rough road to the cove,

A FEMALE SKULL

TAKEN FROM THE HOT MUMMY CAVE ON KAGAMIL ISLAND. PROBABLY THAT OF A FAVORITE MEMBER OF A FAMILY, PERHAPS A FAVORITE WIFE, BURIED SEPARATELY, IN MOSS, IN A WOODEN DISH.

CHILD MUMMY IN ITS CRADLE

FROM THE WARM MUMMY CAVE ON KAGAMIL ISLAND. LITTLE MUMMIES OF THIS NATURE, AS IS KNOWN FROM EARLY RUSSIAN RECORDS, WERE SUSPENDED FROM RAFTERS IN THE CAVE.

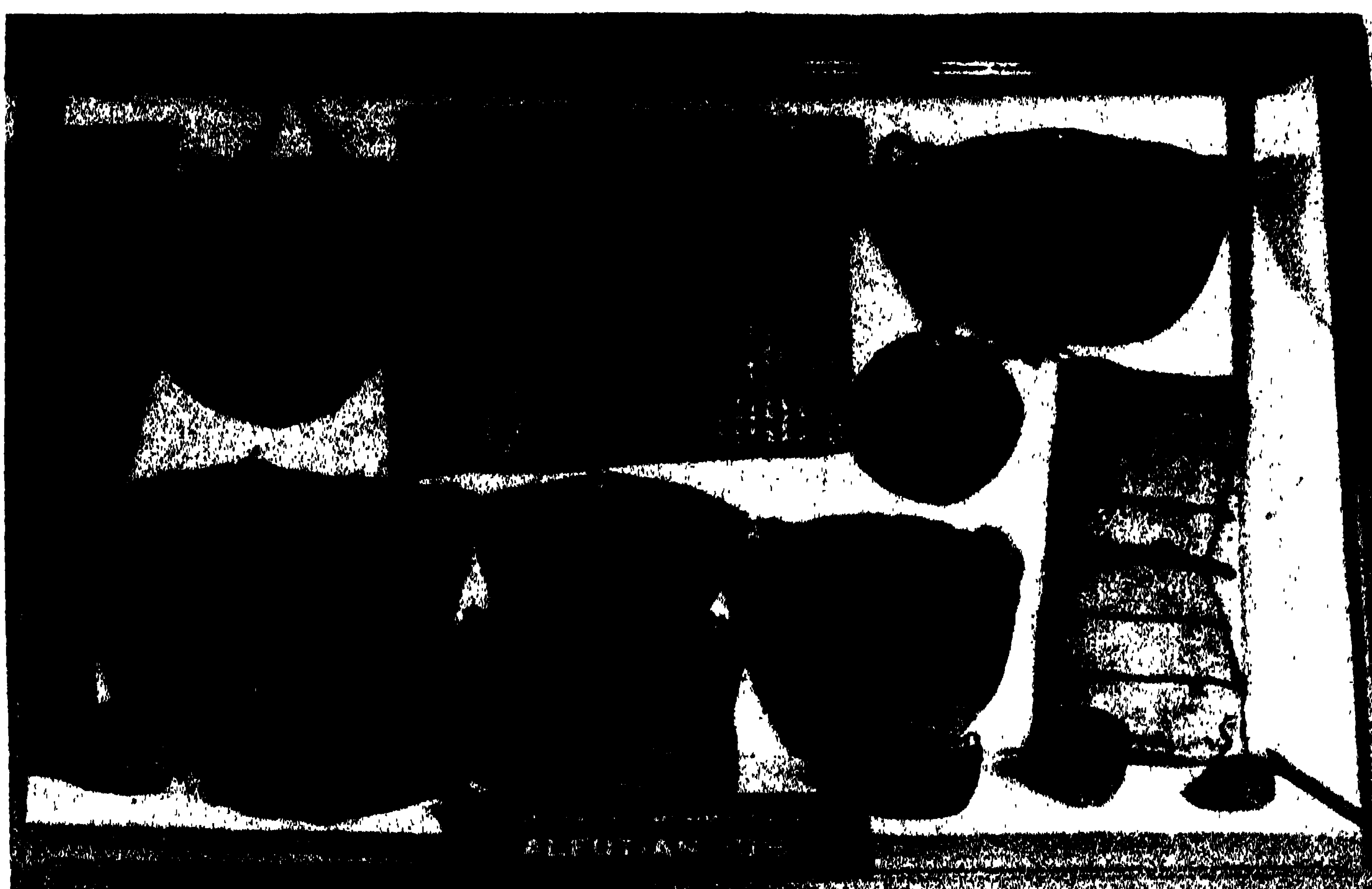
but now we had also the bulky collections. There was but one thing to do and that was to arrange to move everything by relays. I strung the party over the boulders at such distances that the sacks, etc., could be handled or safely thrown over from one to the other, the last man to pile everything on the nearest greater boulder; after which the whole process was repeated. It now started also to drizzle and the gnats were bad. There were but five of us, the rest having gone or been sent ahead, to bring

BURIAL OF A NEW-BORN INFANT, IN A WOODEN DISH

THE BONES ARE IN SOFT MOSS. THE OFFERINGS SEEN ARE A BIRD'S EGG AND WING. THE WHOLE WAS ORIGINALLY ENVELOPED IN A MATTING, SHREDS OF WHICH ARE STILL SEEN ON THE LEFT. FROM THE KAGAMIL WARM CAVE.

the lunch (which never came) and to keep in touch with the two boats which were riding out in the cove. A considerable difficulty was encountered on the steep slope upward—there was danger of both men and specimens sliding down, and no space to pile up the parcels of the end of the chain; but that, too, was overcome. The trip from the cave to our cove took over one and three quarters of an hour. Meanwhile, the rocks and grass got all wet, which made going more difficult. But the relays worked admirably to the end. No one got real tired out. The surf boat was manipulated into a little inlet between a couple of huge boulders, some of the boys from the ship held it with oars so that the swell would not throw it on the rocks, the parcels were relaid bit by bit to one of the boulders, from there tossed over to two men in the boat, and when somewhat more than half of the collections were on, the surf boat went out to transfer everything to the dory. It then came back, was loaded with the remainder, took ourselves, and by 6:00 P.M., with weather steadily roughening, we were once more on board the "Chelan," added our harvest to that of the previous day, saw everything covered and safely tied on the deck; and before we were through with our shower the ship was on its way to Unalaska, where we reached the next day. Meanwhile a wire was sent to the Alaska Commercial Company to have ready on the dock 22 old tierces. On arrival we found these on the dock, they were at once taken aboard, and within three hours everything was packed and safe. In six weeks it was without damage in Washington, and then, for over a month, there was the rare treat of unpacking and examining everything. And it proved a wonderful material.

Notwithstanding these collections, the



MATS, BAGS AND BASKETS FROM WARM MUMMY CAVE OF KAGAMIL ISLAND

THESE OBJECTS WERE FOUND BURIED WITH THE BODIES, EITHER OUTSIDE OF THEM OR WITHIN THE MUMMY BUNDLES THEMSELVES. THE BASKET IN THE CENTER IS OF EXCEEDINGLY FINE WORKMANSHIP, AND THE OBJECTS THROUGHOUT SHOW AN ASTONISHINGLY HIGH DEGREE OF NATIVE ART.

two caves on Kagamil remained "unfinished business"; besides which there was the possibility, backed by some hazy rumors, of still another such cave on the island. For this reason a second visit, thanks to the Coast Guard, was made to the locality in 1937, and a third in 1938. In these visits another large cave was found, but it was empty; the rough southwestern coast of the island and the southeastern point were explored, without result except the location of a small and not very old site in the lowland, with a large barabra depression on the flat part over the cliffs near the location of the warm cave; and several rock-shelters, with burials, were discovered in the cliffs to the east of the warm cave and excavated. Both the warm and the cold caves were finally quite exhausted, without adding materially to our previous collections; but in the warm cave, in the lowest parts of the "salt" deposits, there came to light the remains of a number of cremations; and under a large slab that lay in the middle beneath everything, there were revealed, undisturbed, the remains of a group-cremation of several individuals, doubtless slaves.

On both the 1937 and the 1938 trips other caves and rock-shelters, also, were located and explored. The field notes relating to all this read as follows:

June 17, 1937. On the small Coast Guard ship "Morris," Lt. A. J. Carpenter. Leave Unalaska in the morning for Veselov (corrupted to Wisslow) island or rock, 13 miles west from Dutch Harbor. Weather half fair, sea moderately rough, nevertheless felt. Ship anchors about one third of a mile off the rock. Lunch with crew of dory, and then to the volcanic pile. Grows forbidding as approached, black rough sides, a huge hideous vertical rent in midst to the seaward. No beach or cove. Have to fasten to rock itself on landward side, where water heaves least. The islet is found to be a mass of volcanic conglomerate, a ferruginous lava warty with inclosed cinders and rocks, very rough and steep; but the "warts" are hard and like welded in, so that all afford firm hold and enable us to "goat it" over the sides. Above half way up we find a shallow shelter under a ledge, and in this 3 lower jaws. Excavate to about 2 feet deep, find other bones and a number of cultural specimens. Have cleaned everything. Remains *Aleut.*

June 18–19. Reach Chernovski Harbor, Unalaska Island. On a long and broad gravel bar, between sea and harbor, decaying remains of a Russian-time Aleut village, and to the left of this an imposing older mound-site, with a 35 × 140 feet barabra depression on the top. In distance to right, under a cliff, a rock-shelter, and further seaward a cave in another cliff, now empty but once said to have had burials. Excavation in the rock-shelter yields a number of old Aleut burials. Explore coast for caves over four miles eastward, without result; and nothing of that nature known of elsewhere in the region by local sheep herders.

June 20. Quiet, but sky murky. Reach Nikolski, Umnak. Krukhov, an old native, tells about the "mummy cave" mentioned by Veniaminov, on Shiprock.

June 21. Reach Kagamil. Sea moderate, but a heaving surf. Find in our beach a little "haven" among the boulders, just large and safe enough for the dory. Boys eager. Work whole afternoon in the two caves—just gleanings—but among these a fine wooden labret. Drizzle all P.M.

June 22, 5 A.M. Lovely morning, and nearby volcanoes, Mt. Cleveland and Mt. Carlyle, in all pristine beauty, like huge almost supernatural great pure-white cones, within 10 miles of us; but begins to cloud up before I can bring up my camera.

Ashore, with all my boys and some officers and men from ship, right after

VOLCANOES SHISHALVIN AND IVANGTSKI ON ALASKAN PENINSULA
ON CLEAR NIGHTS, WHICH HOWEVER ARE RARE, THESE PRESENT A MAJESTIC APPEARANCE. THE SHISHALVIN, APPROXIMATELY 8000 FEET IN HEIGHT, OCCASIONALLY SMOKES AND LIGHTENS THE NIGHT WITH A PILLAR OF LURID LIGHT THAT REACHES TOWARD THE SKY.

breakfast. Explore crags between the two caves, and soon locate a rock-shelter with some old burials. Explore also to NW along rough coast—find caves, especially one—but nothing in them.

Rock-shelter proves exceptionally rich, full of bones and skulls, but mostly female. Of mats and other perishables but traces. Two bodies cremated—doubtless sacrificed slaves. Men from ship very helpful—none hurt, and everybody living adventure: Good calm day, though swell outside our "haven." Seals a few yards from bouldery shore pop up from kelp to watch the visitors. Beach smokes to-day in many places. Lunch among the rocks. A hungry fox comes near one of the men—is fed on sardines thrown to it—then curls down and goes to sleep. At times eery views of the volcanoes through mists. . . . Late P.M. return to Chernovski.

June 23. To-day to examine the Split-Rock isle near Kashega, reputed to have a "mummy cave" or shelter.

Reach Rock near 8:30. Is completely split crosswise—some earthquake. About 200 feet in maximum height, slopes of talus, steep cliffs. Climb on top of smaller part—find two skulls there, also a superficial skeleton, with some stone points. A couple more skulls on the grassy slopes. Larger portion has a number of caves and rock-shelters; the caves now empty, rock-shelters worth exploring. Excavate a deeper one on the SE side, find burials, also four new type stone lamps—two quadrilateral. Dig also on top—two more skeletons.

Have endeavored to climb, too, the larger part of the rock. Found only one possible way and that very difficult. But the survey people had been here and left hanging down a sash-cord with copper-wire core. With the help of this, three of us reached the top—only to find, when

AN EXCEPTIONAL VIEW OF SMOKING MOUNT CLEVELAND

SEEN LOOKING WEST FROM APPLEGATE COVE OPPOSITE KAGAMIL ISLAND. THERE ARE SCORES OF THESE GREAT VOLCANOES IN THE ALEUTIAN CHAIN. PROBABLY NONE OF THEM IS QUITE EXTINCT. THEY ARE RARELY REVEALED, BEING COVERED WITH MISTS.

wanting to descend, that near where anchored the cord had so rotted that it parts when tested. How it held while we were scrambling up is unexplainable. The top was very grassy, but showed traces of natives. This isle ('Split-Rock') was known to the natives as a former refuge, and also as a place where, on the top, there used to be some temporary habitations, and burials. Based on the native information to this effect, the rock was visited in 1928 by the Stoll-McCracken expedition for the American Museum of Natural History (N. Y.), and both parts of it were scaled, with the results of finding, on the top of the larger portion, aside of the depressions of old habitations, a "driftwood sarcofagus containing four 'mummies' "; and the location of a burial rock-shelter on the south end of the smaller portion, which gave a small collection of skeletal as well as other materials.[12]

Toward evening we tried to reach Shiprock, a great high isolated "rock" in the Umnak Pass, and came near—but current proved too strong for our facilities and so had to return. Seven days—much good fortune—but no mummies. . . .

[12] Reported by E. M. Weyer, in an article on "An Aleutian Burial," *Anthrop. Papers Am. Mus. Nat. Hist.*, 31: 217–238, 1929.

(*To be continued*)

THE DYNAMICS OF SNEEZING—STUDIES BY HIGH-SPEED PHOTOGRAPHY[1]

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SNEEZING, the violent expulsion of air from the mouth and nose, is an involuntary, reflex, respiratory act. It is caused by irritation of certain nerve-endings in the mucous membrane of the nose, or by stimulation of the optic nerve by a bright light.

By the early Greeks and Romans, a sneeze was considered a sign or omen from the gods. This venerable belief survives in the still wide-spread custom of saying "God bless you," or its equivalent, when a person sneezes. Sir John Lubbock,[2] in his "Origin of Civilisation and the Primitive Condition of Man," states that a sneeze was evidence that the sneezer was possessed by some evil-disposed spirit. To-day, in the field of public health, the activities of this "spirit"—bacteria and viruses in sneeze droplets—are recognized in the transmission of certain respiratory diseases.[3]

[1] Contribution No. 174 from the Department of Biology and Public Health.

[2] Sir John Lubbock (Lord Avebury). "Origin of Civilisation and the Primitive Condition of Man." Ed. 7. Longmans, London, 1912.

[3] W. F. Wells, M. W. Wells and Stuart Mudd. *Am. Jour. Pub. Health*, 29: 863, 1939.

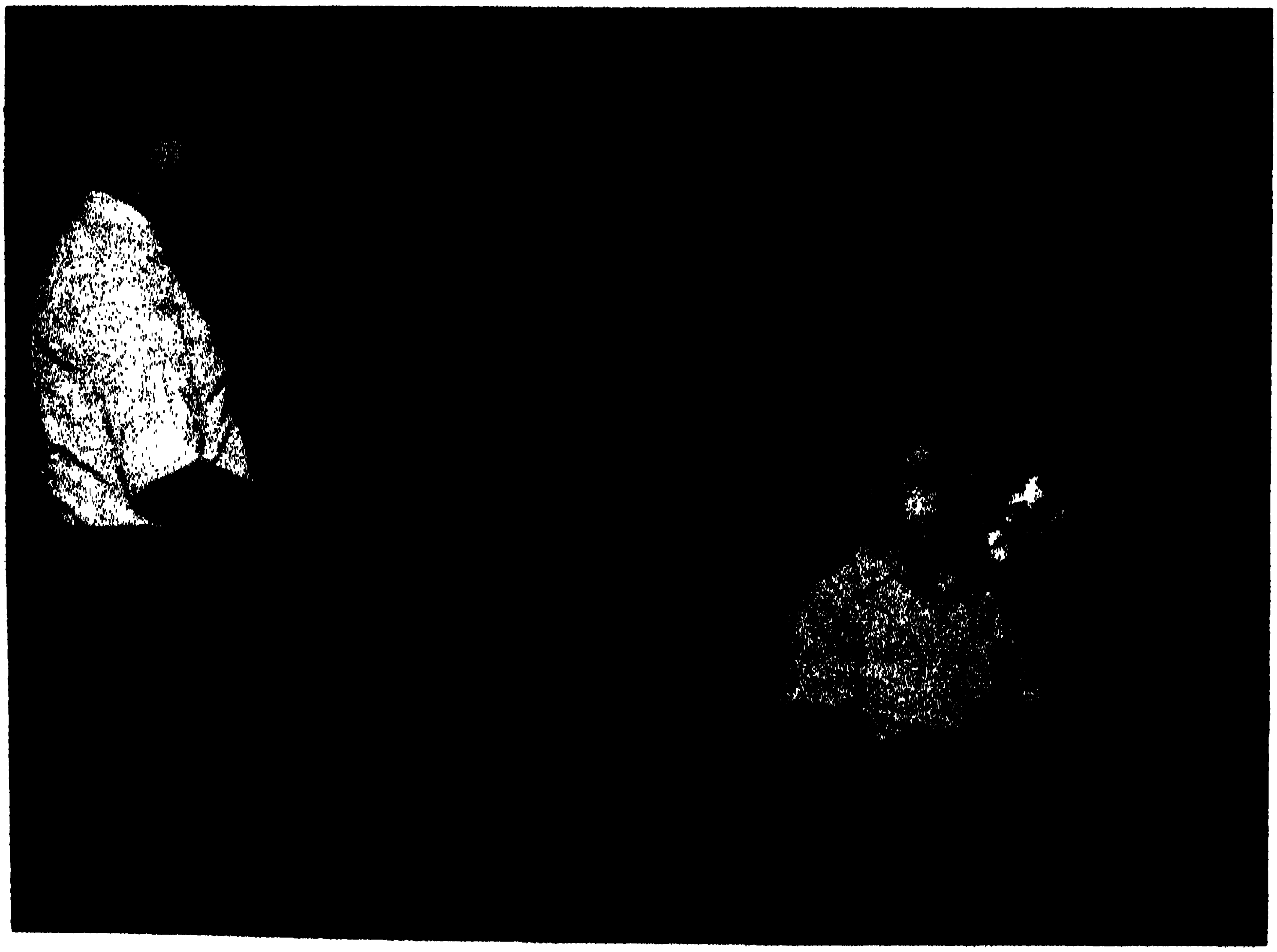

FIG. 1. ARRANGEMENT OF SUBJECT AND APPARATUS FOR PHOTOGRAPHY.

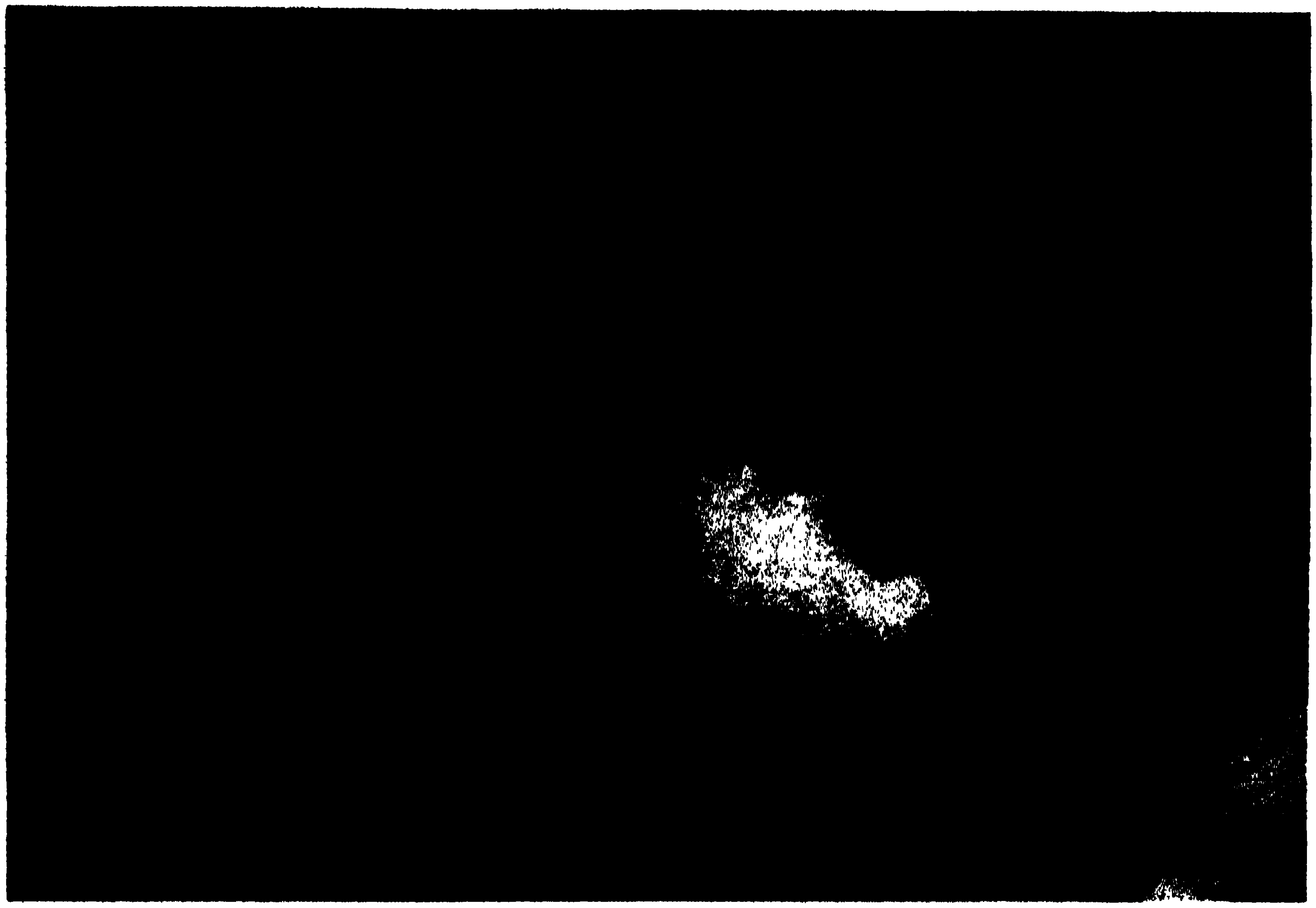

FIG. 2. A VIOLENT SNEEZE, PARTIALLY STIFLED.

Recent investigations in air bacteriology and on air-borne infection have justifiably reopened the question of the role of air in the transportation of pathogenic microorganisms. Of the importance of droplet infection there seems to be little doubt, but the part played by the air-borne droplet nuclei, which result from the evaporation of droplets proper, has not been as clearly delimited. Experimentally, little is known of certain of the characteristics of sneeze droplets, although such factors as number, size, velocity and rate of evaporation are concerned in their dissemination and in the production of droplet nuclei. The importance of the definition of conditions which introduce bacteria into the air and the significance of the particle size and the resulting state of suspension in the air have been pointed out by Wells *et al.*[4]

In a preliminary study of droplet infection of air by sneezing, using high-speed, single-flash photography for demonstrating droplet production, Jennison and Edgerton[5] made certain incidental observations relative to the sneezing process itself. "Still" pictures have been complemented by high-speed motion pictures, and analysis of the records reveals a number of interesting points about the dynamics and external manifestations of this respiratory reflex. The records are of general physiological interest, as well as demonstrating graphically the possibilities of droplet infection.

Apparatus and Methods

The photographic technique utilized recent, unpublished modifications of the light sources and control instruments developed by Edgerton *et al.*[6,7,8] for

[4] W. F. Wells, *et al.*, American Public Health Association Year Book 1939–1940, pp. 99–101.

[5] M. W. Jennison and H. E. Edgerton, *Proc. Soc. Exp. Biol. and Med.*, 43: 455, 1940.

[6] H. E. Edgerton, K. J. Germeshausen and H. E. Grier. *Jour. Appl. Physics*, 8: 2, 1937.

[7] H. E. Edgerton, K. J. Germeshausen and

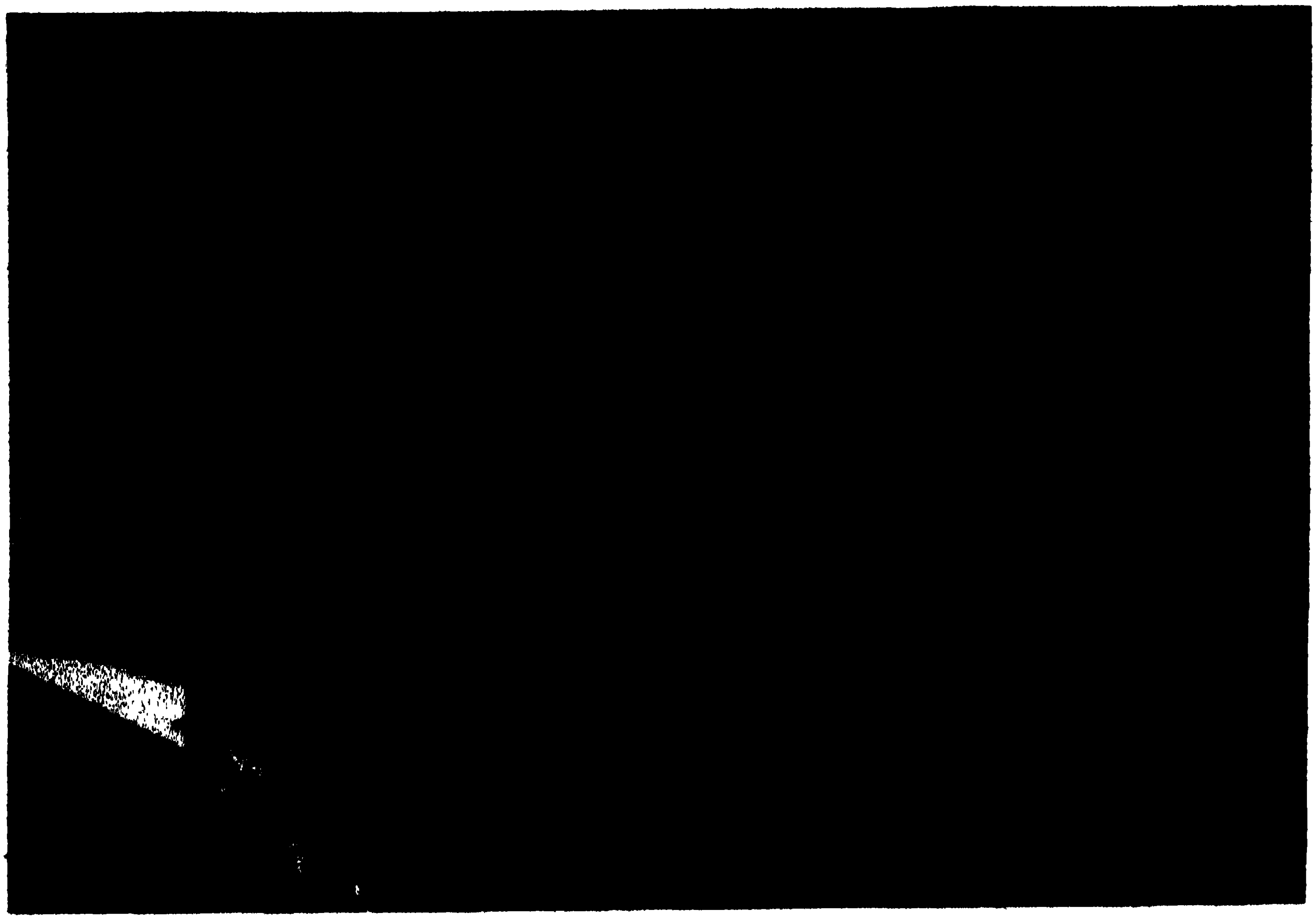

FIG. 3. MULTIFLASH METHOD FOR DETERMINING DROPLET VELOCITY.

stroboscopic illumination and high-speed photography, which technique substitutes an instantaneous flash of light for the relatively slow opening and closing of a camera shutter. The light illuminates the object to be photographed with an intense flash of short duration, "stopping" motion by providing an exposure-time so short that the object does not move any appreciable distance during exposure.

The light source, which was placed at the side of the subject's face away from the camera (Fig. 1), consisted of a light-tube in a parabolic reflector; illumination was produced by the discharge of a condenser through this tube. The light was placed in such a position that the droplets were illuminated with a dark-field effect, thereby standing out sharply even in daylight, indoors, and giving photographic images larger than actual droplet size, particularly when not in sharp focus. The intensity of the light is so great that it is unnecessary, indoors, to consider the amount of other light in making camera adjustments. A white screen in front of the subject reflected back enough light so that the side of the subject's face which was towards the camera photographed clearly.

For the single-flash "still" pictures, a 56 microfarad condenser, charged to 2,500 volts, discharged through a spiral, argon-filled light-tube. A photographically effective duration of flash (exposure-time) of about 1/30,000 of a second was found sufficient to "stop" most sneeze particles. For multiflash "still" pictures (used in determining droplet velocity), spiral light-tubes were used with 1-microfarad condensers at 3,000

H. E. Grier, *Photo Technique*, 1 (5): 14 (October), 1939.

[8] H. E. Edgerton and J. R. Killian, Jr. "Flash! Seeing the Unseen by Ultra High-speed Photography." Hale, Cushman and Flint, Boston, 1939.

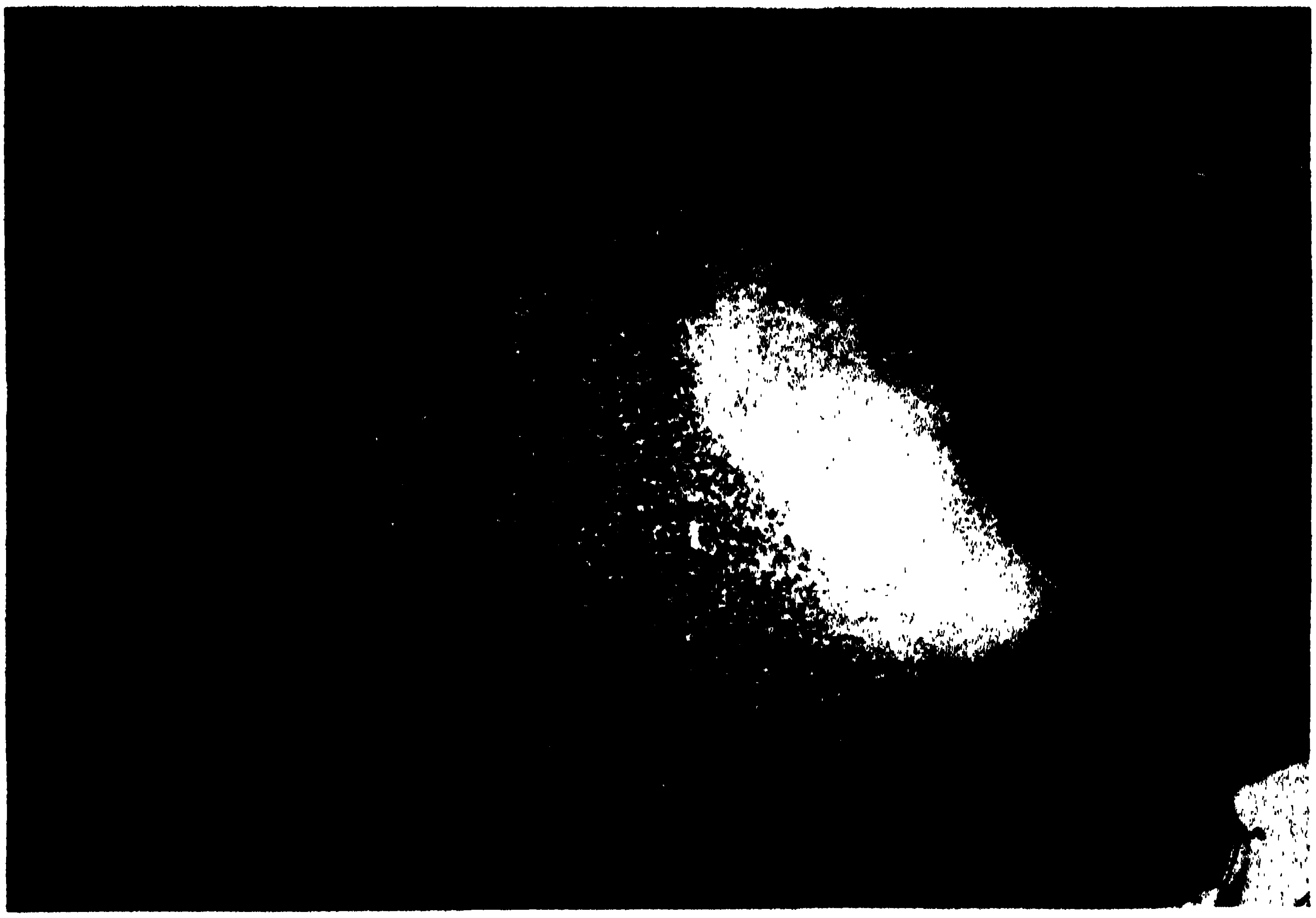

FIG. 4. A VIOLENT, UNSTIFLED SNEEZE, NOT QUITE COMPLETED.

volts, and exposure-times of 1/100,000 of a second. Both types of "still" photographs were taken with an ordinary camera, with apertures of f4.5 to f11, on 9 x 12 cm. Verichrome film. It was convenient, but not essential, to have an electrical contact on the camera shutter; this contact set off the flash when the shutter (set at 1/100) was wide open.

For the motion pictures, a quartz-capillary light-tube was employed, with a 1-microfarad condenser charged to 1,200 volts. In the motion picture camera (without shutter) the film is moved past the lens at a constant, high speed. Each time the film has moved the distance occupied by one picture, the subject is illuminated by a flash of light. The time at which the flash occurs is controlled by a commutator attached to the film-driving mechanism. The duration of each flash is about 1/100,000 of a second, which effectively "stops" motion during exposure. A timing device in the camera records the film speed directly on the film. The sneezes were taken at speeds up to about 1,300 frames per second, on 35 mm panchromatic film.

Because of the lower light intensity, and for other technical reasons, very few *small* droplets showed up in the motion pictures and in the multiflash "still" photographs as compared with the numbers obtained with the single-flash technique.

Droplet velocities were obtained by three methods: *a*. The order of magnitude was estimated from single-flash photographs in which the exposure-time was long enough (1/30,000 to 1/15,000 of a second), so that the fastest droplets produced a path of measurable length on the film during exposure[5] (Figs. 2 and 7). This method is relatively inaccurate, however, because the exposure-time can not be determined precisely. This is a consequence of the electrical characteristics of the light source, which, after

quickly reaching a maximum brightness, tapers off in intensity, the point beyond which the light is photographically ineffective being only approximately determinable; *b*. Velocities were determined very precisely from measurements on the high-speed motion pictures (Fig. 9), the speed of which is known to within a fraction of a per cent.[6]; *c*. Multiflash "still" pictures also allow precise determination of velocity.[7] Two lights were used, each of which flashed once with a known time interval between the two flashes. This interval was determined by photographing, in the field of the sneeze, a disc spinning at known speed. A line on the disc appeared as an angle after consecutive flashes, and from the angle and the droplet displacement in the calculated time, droplet velocity was computed (Fig. 3).

Most of the subjects used were men, since they sneezed more readily, more violently and had less tendency to stifle the sneeze than women. Some of the subjects had colds, others hay-fever, and others were normal. Many of the sneezes were initiated by rubbing a little snuff into the nostrils. No water or other materials were held in the mouth. The subjects were asked to sneeze as naturally as possible but without consciously stifling the expiratory effort. There did not appear to be any marked differences between "normal" sneezes and those "artificially" induced, although the snuff often produced several spasms in quick succession.

Results

The observations are based on some 300 "still" pictures and 4 motion pictures, on 16 subjects at various times. While a sneeze consists of two stages—a sudden inspiration, followed by a forcible expiration—we have been concerned chiefly with the expiratory phase.

All subjects always had the eyes closed at the instant of expiration; often the

FIG. 5. A COMPLETED SNEEZE.

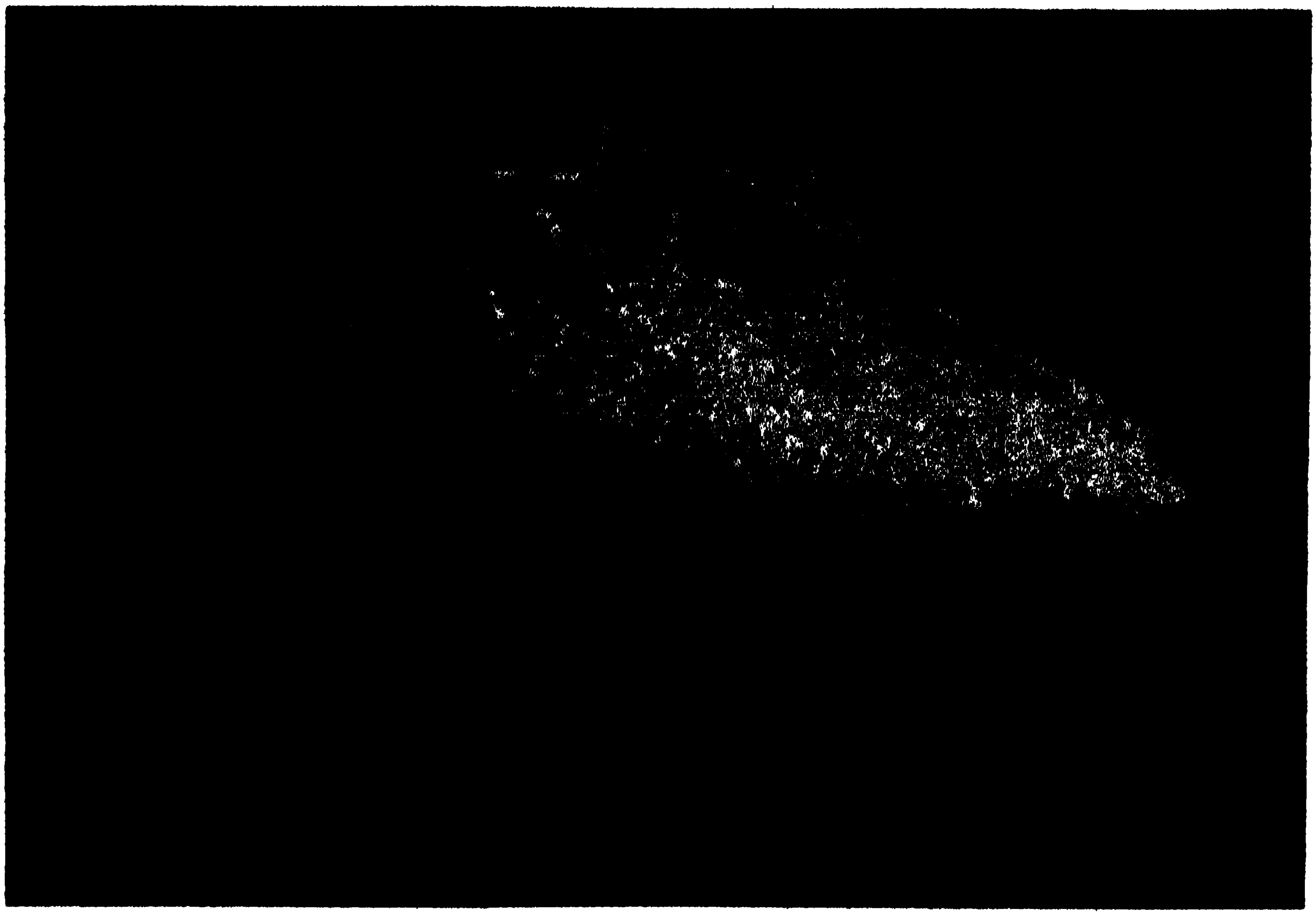

FIG. 6. SNEEZE FROM SUBJECT WITH A BAD COLD.

closing occurred coincidentally with the inspiration. This was not due to the light, which was coming from behind the subject. Furthermore, experiments with the light shining into the subject's eyes showed that there was a measurable lag between the light flash and the closing of the eyes. In sneezing, the eyes were closed at the time the light flashed, hence the closing stimulus occurred before the flash. Involuntary closing of the eyes appears to be part of the sneezing reflex (Figs. 2–8, 9).

At the inspiration, in most subjects, the head was involuntarily thrown back, and the mouth simultaneously opened wide (Fig. 9). Between the inspiration and expiration there may be an appreciable time interval, during which one or more false starts in expiration may be made. A typical expiratory phase consisted of a quick "down-stroke" of the head, a closing of the mouth and the forcible ejection of air and droplets. Usually the mouth was more nearly closed at the climax than in Fig. 9. In most cases the upper and lower teeth were closely approximated, as shown clearly in Figs. 4 and 5. The extent to which the mouth is closed, and particularly the approximation of the teeth largely determine the number and size of the droplets, that is, the efficiency of "atomization." Most of the droplets appear to originate from the saliva in the front of the mouth, more, and smaller ones, being formed in the air stream when the orifice is restricted (*Cf.* Figs. 4 and 9). The majority of sneeze droplets—before appreciable evaporation occurs—are less than 2 millimeters in diameter, and many are less than 0.1 millimeter, as determined from photographic enlargements, although in subjects having viscid mucous secretions from colds or hay-fever larger drops and masses are common, as a result of less effective "atomization" (Fig. 6).

Precise measurements of droplet speeds in violent sneezes have given "muzzle velocities" as high as 152 feet per second for some droplets, but speeds less than this are more usual. While this is the maximum rate we have recorded, we have not tried experimentally to determine the upper limit. For technical reasons, most of the smaller—and possibly faster—droplets did not photograph in the techniques which allowed accurate measurements of velocity.

Estimates of the pressures necessary to obtain the droplet velocities found have been calculated from thermodynamic formulas for air flow through orifices. A velocity of 150 feet per second would require a pressure of some 10 to 12 millimeters of mercury, not considering inertia of the droplets or friction. This pressure is about one fifth of the *maximum steady* pressure which a man can exert by blowing into a manometer. Since four times this pressure would be required to double the velocity, it is probable that even in violent sneezes, the fastest droplets do not have an initial velocity much over 300 feet per second, unless, perchance, the *instantaneous* pressure in a sneeze is markedly greater than about 60 millimeters of mercury.

The distance to which sneeze droplets will be expelled, and the distance to evaporation, depend upon droplet size, velocity, temperature and humidity of the surrounding air, and the moisture content of the particles. One would expect mucous secretions to evaporate less readily than saliva or water. Most droplets, because of their small size, are not expelled farther than two or three feet, under ordinary conditions, as shown both by photographs and by glass plates and culture dishes placed in front of the mouths (Fig. 7). Small droplets, at high velocity, quickly evaporate to produce air-borne droplet nuclei (Fig. 8); larger ones, as in Fig. 6, will be expelled farther, then fall to the ground.

The actual mechanism of droplet for-

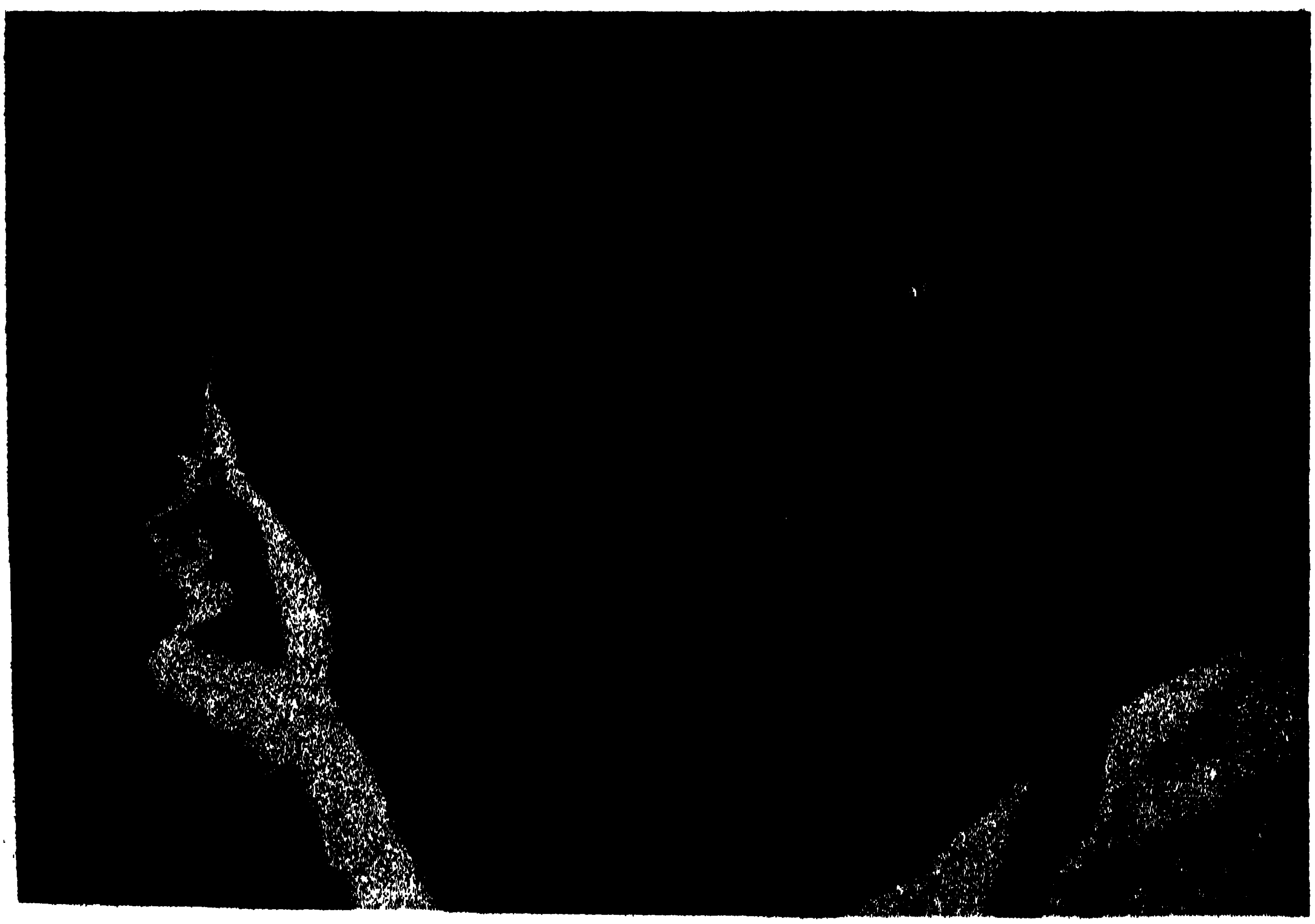

FIG. 7. SNEEZING ONTO A CULTURE DISH TO COLLECT BACTERIA.

mation from secretions, in sneezing, is the same as that described and illustrated by Castleman[9] for the "atomization" of other liquids in an air stream. A portion of a mass of saliva or other secretion is caught up by the air stream, and, being anchored at one end, is drawn out into a fine filament. This filament is quickly cut off by the rapid growth of a dent in its surface, and the detached mass, being quite small, swiftly draws itself up into a spherical drop. The higher the air speed, the finer will be the filaments, the shorter their lives, and the smaller the drops formed, within limits. Droplet formation from a filament of saliva is illustrated in a previous paper,[5] and also is shown here, although not clearly, in Fig. 6, and in frames 70 and 71 of Fig. 9.

The photographs show that there is great variation in numbers of droplets with the type and with the violence of the expiratory effort. Violent, unstifled sneezes, particularly those in which the mouth was well closed at the climax, gave droplet numbers in the tens of thousands (Figs. 4 and 5). Stifling the sneeze results in fewer and in smaller droplets; this act may also tend to produce a greater velocity of expulsion (Fig. 2). On a culture dish directly exposed to sneeze droplets (Fig. 7), thousands of bacterial colonies will develop.

In both stifled and unstifled sneezes, the number of particles issuing from the nose—when, indeed, any could be detected from this source—was insignificant compared with the number expelled from the mouth. Furthermore, in the relatively few cases in which there were particles that appeared to be of nasal origin, excessive secretions of mucous were present in the nose, and larger *masses*, not small *droplets*, resulted from the sneeze. These facts are of more than

[9] R. A. Castleman, Jr. *Bureau of Standards Journal of Research*, 6: 369, 1931.

FIG. 8. DISTRIBUTION OF DROPLETS IMMEDIATELY AFTER EXPULSION.

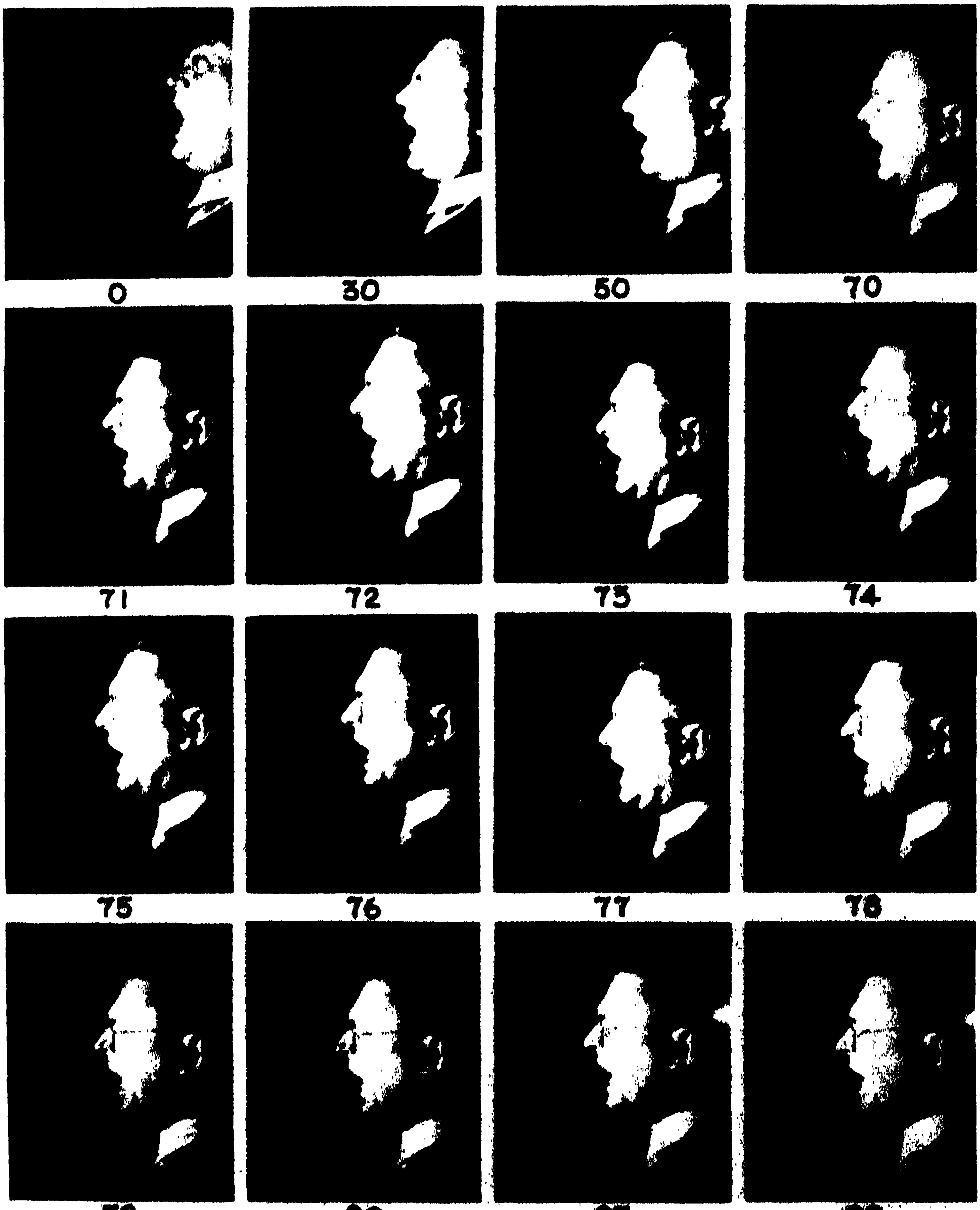

FIG. 9. SUCCESSIVE STAGES IN THE EXPIRATORY PHASE OF A SNEEZE.
SELECTED FRAMES FROM A HIGH-SPEED MOTION PICTURE HAVING INTERVALS OF 0.0008 SECONDS BETWEEN CONSECUTIVE FRAMES. NUMERALS REFER TO NUMBER OF TIME INTERVALS FROM THE START OF THE "DOWN-STROKE" OF THE HEAD. THE SMALL DROPLET IN FRAMES 71–74 HAS A VELOCITY OF 94 FEET PER SECOND; THE LARGER MASS IN FRAMES 72–80, A SPEED OF 61 FEET.

passing interest in relation to infection, because of the differences in the microbic flora of the two regions. Organisms of the mouth have usually received less attention than those of the naso-pharynx, in connection with both droplet infection and air-borne infection. But it is the *small droplets*—those originating in the mouth—which evaporate while in suspension in the air, and which therefore are of most direct importance in air-borne infection.

The fact that in most of our photographs of droplet expulsion no material could be detected coming from the nostrils, might result if particles from this source were caught in the blast of air and droplets from the mouth. However, records of early and late stages of sneezing usually confirm the negative observations made on the intermediate stages. While it does not necessarily follow that no air or particles were expelled through the nose, it appears that most of the pressure was released through the mouth. This is of physiological interest, in that Winton and Bayliss[10] state: "The sneeze . . . consists . . . of a sudden strong forced expiration, during which the glottis remains open, but the communication between pharynx and the mouth is closed by contraction of the anterior fauces, so that *the air from the lungs is driven entirely through the nose.*" (Italics mine.) This is obviously not the whole story, except possibly when weak sneezes are intentionally stifled, although we have observed that sometimes the involuntary closing of the mouth in a weak sneeze may result in *most* of the pressure being released through the nose. Experimentally it is difficult, in violent sneezes, to *prevent* most of the pressure from being released through the mouth, even if one tries. Our observations as to the end result are as stated by Best and Taylor:[11] "During the first part of the expiratory effort the way into the mouth is blocked by the elevation of the tongue against the soft palate, the blast of air thus being directed through the nose. *Later, the resistance offered by the tongue is removed, the air then escaping through the mouth.*" (Italics mine.)

The time involved in a sneeze is of interest, but not exactly determinable unless the beginning and end are taken rather arbitrarily. In Fig. 9, a sequence from the shortest expiratory phase obtained is recorded, taking as the beginning the start of the "down-stroke" of the head, and as the end the lowest point in this movement and the disappearance of the droplets from the photographic field. Partly for reasons of technique, and partly because of the type of sneeze, very few droplets show in this figure. These motion pictures were taken at 1,260 frames per second, and the expiratory effort as shown took 0.07 seconds. In motion pictures of three other subjects, the exipratory phase lasted longer—between 0.1 and 0.2 seconds.

Thus it is evident that the mechanics of sneezing are intimately bound up with the production, dissemination and even the potential infectivity of the resulting droplets. Until now it has been the impression that the pious aspiration uttered when a person sneezes was for the benefit of the sneezer, but obviously the ejaculation should be intended also for the protection of the potential victims. This germ-scattering performance certainly is nothing to be sneezed at!

[10] F. R. Winton and L. E. Bayliss. "Human Physiology." Ed. 2. P. Blakiston's Son and Company, Philadelphia, 1937.

[11] C. H. Best and N. B. Taylor. "The Living Body." Henry Holt and Company, New York, 1938.

THE HEART THAT FAILS

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EVERY announcement of a sudden fatality attributed to the heart creates the desire for a more intelligent comprehension of the mechanisms and reasons for such calamities. Commonly used expressions, such as "heart attack," "heart failure," "cardiac shock," "coronary attack," etc., are merely euphonious phrases; they do not satisfy as an explanation for inquiring minds. We read of the sudden extinction of life under a variety of conditions and circumstances: a distinguished citizen, apparently well, or certainly not significantly indisposed, is suddenly taken off at the dinner table or on the golf course; another quietly departs this life while asleep. Occasionally, despite the elaborate precautions which now attend administration of anesthetics, a patient's life is lost after a few whiffs of chloroform. Other noxious vapors, such as benzol and many toxic drugs and chemicals, act likewise. Furthermore, the extensive use of various electrical appliances in our homes, trades and professions has created a new hazard of quick cardiac death through accidental electrocution. The cardiac mechanisms by which life is extinguished are essentially alike in all these cases.

Consciousness and life are highly dependent on a continuous supply of oxygenated blood to the brain. Other organs of the body withstand complete absence of blood flow for considerable periods; but in the case of the brain it is only a matter of minutes or seconds before serious effects are produced. As every one is aware, blood is circulated by the pumping action of the muscular chambers of the heart, called the ventricles. If their pumping action ceases even for 3 to 5 seconds, temporary unconsciousness may occur. Failure to contract for 15 to 20 seconds can lead to twitchings or convulsions, while complete stoppage lasting 2 to 5 minutes is rarely followed by spontaneous recovery.

However, the types of fatal cardiac accidents which we are considering are not caused by standstill of the heart; on the contrary, the contractile efforts are significantly increased. What actually happens is that the rhythmic coordinated beats are suddenly converted into an incoordinate type of action, called ventricular fibrillation (fi-bril-lá-tion). It is of primary importance to form a mental picture as to what such a transformation involves.

Normally, the force for expulsion of blood from the heart is created by the simultaneous contraction of millions of microscopic muscle fibers which form the walls of the ventricles or myocardium. During ventricular fibrillation the muscle fibers still contract but in totally disorganized fashion, sometimes referred to as delirium of the heart. Fibrillary contractions are somewhat similar to shivering or convulsive contractions of skeletal muscles. Any one who has experienced or witnessed a severe chill or convulsion appreciates that vigorous and violent contractions can be functionally quite as useless as though the muscles remained at rest. In short, in cardiac or skeletal muscle, effective action demands not merely that muscles contract but also that they do so in a sequential and coordinated manner.

Fibrillation may also be compared to the action of an automobile engine in which the gas mixture in each of its eight cylinders is exploded very frequently but entirely at random. Such

an engine, like the fibrillating ventricles with their millions of tiny muscle cylinders, all firing out of phase, would consume more fuel but produce no useful work. In the case of the ventricles, this means that blood is not expelled, that pressures promptly fall to zero in arteries, and that death follows in 6 to 8 minutes, owing to anemia of the brain.

While the real cause of sudden cardiac death has continued to baffle physicians until comparatively recent times, ventricular fibrillation has been known to physiologists since its recognition by Ludwig in 1850. This lag in application of knowledge has been due to the fact that ventricular fibrillation is a physiological disorder, incapable of recognition, postmortem. It was only through the development of electrocardiography with the shuttling of problems and discoveries between the experimental laboratory and the bedside that clinical diagnoses have become possible.

During the 90 years which have elapsed since Ludwig's description of fibrillation, physiologists have directed their talents toward the solution of many problems. Some of the more important ones are (1) the interpretation of the nature of the fibrillating process; (2) the establishment of the conditions which are responsible for its initiation, (3) the development of methods for defibrillating the ventricles and restoring normal beats before the brain has been irretrievably damaged, and (4) attempts to render the ventricles less susceptible or refractory to fibrillating agents.

Nature of Ventricular Fibrillation

Coordinated, effective action of the ventricles is normally achieved, through an ignition system, somewhat as in an automobile engine. Seventy-two times per minute—more or less— combustible material in the millions of tiny muscle cylinders is exploded by a brief electrical impulse. This impulse is generated in a small knot of tissue in the right auricle, known as the *sinus node*. It is distributed to the ventricles over a special system of muscular wires and in such a manner that it fires all the muscle fractions approximately at the same time. The simultaneous explosion of combustible material results in the vigorous contraction of the ventricles as a whole. It is amply established that, during fibrillation, the electrical impulses no longer travel over this organized route, but spread at random and in a disorganized fashion throughout the myocardium. In so doing, they still cause contractions of the muscle fractions; but entirely in a haphazard manner.

Opinions are divided as to how this disorganization is brought about. According to one school of observers, a large number of new ignition centers are created throughout the myocardium, each of which emits a rapid succession of electrical impulses which spread wherever they can. In other words, the heart is no longer dominated by a single distributor of electric impulses, but by a great number scattered through the heart. In consequence, a conflict of excitation and an asynchronous contraction of the muscle fibers result. According to another school of observers, a condition is suddenly created which permits electrical impulses to escape from an original path, with the result that unrestrained impulses wind and weave way through the myocardium, return more or less to their starting point, traverse the path again, thus establishing perpetual circuits of electrical impulses called "circus rings." In their travel they excite and explode the muscle cylinders which have recovered from a previous contraction. In effect, the original impulses keep on circulating and maintain the fibrillating condition as long as combustible material and oxygen remain availabe. Which of these conceptions is more probably correct? I can answer the query best by reference to some of my personal observations. As a member of

a committee on electric shock, organized in 1928 under the leadership of Professor Howell, one of my projects involved a more detailed study of the fibrillating process by electrocardiographic and cinematographic recordings. These studies demonstrated that, in the mammalian heart, fibrillation is not a constant phenomenon but involves an evoluting series of changes from the moment that it begins until it ceases in 30 to 45 minutes. If the movements of the ventricles are carefully watched for the first two or three minutes or, better still, are photographed and studied through slowed motion pictures, it is seen that the contractions gradually change from undulatory waves to tumultuous convulsive motions and then to fine rapid trembling movements. Analysis shows that, with this transformation of movement the ventricular surface is progressively divided into smaller and smaller areas, which contract faster and faster, each with its own tempo. This is confirmed by tapping electrical impulses at different spots by means of small wicks and recording the electrical potentials so derived by a delicate string galvanometer. In recent studies of this sort, I was able to show that the electrical excitations in three or four different spots bear no relation to one another, and that their frequencies are different. For example, it was found in one experiment that four areas which normally were excited simultaneously 90 times per minute were now excited respectively 840, 675, 600 and 480 times per minute during the tremulous stage. No unitary center or single loop of electrical impulses could produce such results.

Obviously any conception or theory as to the nature of fibrillation must include an explanation of these rapidly evoluting changes in the fibrillating process. We must either believe that more and more centers for excitation arise throughout the myocardium during the first two or three minutes—which is unlikely—or we must adapt the theory of "circus excitation" originally advanced by Professor Garrey of Vanderbilt University to the facts. My own observations incline me toward the belief that at the start, several impulse-fronts sweep over large portions of the ventricles, possibly over muscle bundles. These impulses return more or less to their starting point, approximately retrace their paths, but each time the pathway is somewhat more restricted. After traveling over such circuits four or five times some impulses are extinguished through collision or are otherwise blocked. Separated from the original circuits they form shorter ones, which, in turn, are blocked at the margins. This process continues until the few original long circuits are subdivided into innumerable shorter circuits of shuttling impulses which repeatedly weave their way through small muscle masses. The shorter the circuit, the more frequent the tempo becomes. Such a conception would account for the changing modes of contraction, the formation of smaller and smaller areas, the general speeding up of contractions and the differing rates of excitation in different areas. Regardless of the ultimate correctness of this conception, it may be stated that its formulation as a working hypothesis was responsible for the trial of a new method for defibrillating the ventricles, to be discussed later.

After intervals of about 2 to 4 minutes, still another factor enters into the evolution of the fibrillation process. The contractions become unmistakably weaker and the wavelets travel more slowly. This marks the beginning of the atonic phase. Gradually one area after another ceases to contract, and in 30 to 45 minutes the whole heart has come to rest. Whereas the evoluting changes which precede this atonic phase are attributable to changes in the delivery of electrical impulses, those which occur during this stage are due chiefly

to lack of oxygen. The individual muscle cylinders still have the fuel and they receive the spark, but they fail to contract vigorously owing to the deficiency of oxygen so necessary for combustion. This anoxia, as it is called, develops because, with the very onset of fibrillation, no blood is pumped into the aorta and no blood flows through the coronary arteries which supply the myocardium. As the small reserve store of oxygen attached to the red coloring matter of heart muscle is eventually exhausted, all contractions cease.

The Initiation of Fibrillation

An acceptable theory of ventricular fibrillation must explain not only the nature of the process after it has become established but the mechanisms which allow it to start. Heretofore we have had only vague suggestions as to why some electrical currents cause fibrillation and others do not. A year ago no one had even attempted to offer a logical explanation as to why it starts spontaneously after coronary occlusion or injection of certain drugs. There is no doubt, however, that an understanding of the process involved or even a knowledge of the coefficients necessary for its induction would go far toward lifting experimental studies from an empirical to a scientific plane. Frankly, we are not yet in a position to offer a satisfactory conception of the ultimate mechanisms concerned in starting ventricular fibrillation. But recent discoveries defining the conditions for its precipitation do direct the analysis into narrower channels.

We have stated that fibrillation may follow coronary occlusion, use of various drugs and chemicals—of which chloroform is merely an example—and from passage of electric currents through the heart. It may now be added that it occurs occasionally from mechanical insults to the heart; indeed, it is probable that sudden contusions of the chest, heavy blows of pugilism or entry of a bullet are not without danger in causing sudden death from fibrillation. Personal interest in the subject of fibrillation was originally aroused by the desire to conserve laboratory animals in experimental work, both as a humane measure and a matter of expense. In 1919 a series of investigations was begun to determine how the action of the heart is modified by valvular lesions and other pathological conditions. In these experiments it was necessary to pierce the ventricles of anesthetized dogs with an instrument for recording internal cardiac pressures. Such experiments demonstrated that ordinarily the heart has a remarkable resistance to injury and to severe manipulation. Occasionally, however, the piercing of the heart or an apparently trifling insult led to fibrillation. It occurred in hearts of young and old dogs alike; in hearts that were well or poorly nourished. Various measures were tried to avoid such accidents or to restore normal heart beats; but none proved useful. The question naturally arose as to what determines whether an insult to the heart proves innocuous or leads to fibrillation. We certainly can not be content with its assignment to luck or chance.

In 1923, entirely unrelated experiments yielded a clue as to the reason for such accidental fibrillations. They were designed to test the reactions of the dog's ventricles to brief single induction shocks. It was supposedly well known to physiologists that such shocks cause premature beats when they are applied while the ventricles are relaxing, but are without effect while they are contracting. To my surprise, and contrary to orthodox teaching in physiology, it was discovered that a shock administered during the last moments of contraction also caused a delayed premature beat. In such tests it was a great disappointment when such a shock occasionally caused fibrillation and terminated the

experiment. Similar results have since been reported by physiologists at Columbia University. In view of the fundamental importance of such observations, we studied this problem more carefully. During the past year we have demonstrated unequivocally the following facts:

1. A momentary condenser, induction or galvanic shock, or a single sine wave of a 60 cycle alternating current fibrillates the ventricles, provided it is strong enough and coincides with the last .05 to .06 second of contraction which we have called the vulnerable period of the ventricles. Applied at any other moment of the cardiac cycle an electrical shock is innocuous, no matter how strong.
2. Local application of such shocks suffices; passage of current through a large part of the myocardium is not necessary.
3. The capacity to fibrillate is inherent in heart muscle; it requires no sensitizing or adjuvant action of nerves or hormones to induce it, although admittedly these may affect the threshold.
4. More prolonged direct or alternating currents can fibrillate either because an effective portion of such a current coincides with the vulnerable period of a beat or because they evoke centers which spontaneously release impulses, one of which falls during the vulnerable phase of a beat.
5. Under certain circumstances, such natural stimuli may be strong enough to induce fibrillation.

Into what channels of thought have these discoveries led us in explaining the onset of fibrillation? The demonstration that a stimulus must fall during the vulnerable period in order to start fibrillation indicates clearly that some fractions of the myocardium have become excitable again before the end of systole, that is, before the moment when ejection of blood from the ventricles ceases. Such a theory was developed by the writer in 1927. It is obvious, as Dr. King of Columbia University has properly emphasized, that such an asynchronous cessation of contraction in the muscle cylinders is basic to any concept as to the initiation of fibrillation. But it does not go far enough; something is involved in addition, for, if the stimulus is not strong enough, only one premature beat is induced, presumably through excitation of the same excitable fractions. What this "something" is remains speculative; but we now feel reasonably certain that it must be in the nature of some modification which permits a premature excitation wave to reenter. We are trying to obtain further information as to whether this may be due to local blocking actions of the stronger shocks, to initial excitation of a larger number of fractions and formation of broader wave fronts or to the contingency that the interventricular septum or opposite ventricle are excited over natural or abnormal pathways. The question remains, what are the coefficients which determine induction of an apparently spontaneous fibrillation after use of certain chemicals or drugs and during coronary occlusion? We have not studied the former, but our most recent experimental observations suggest an explanation as to how it is produced after occlusion of a coronary vessel.

We may reiterate that, in order to induce fibrillation, we must have an effective stimulus which may be of brief duration but which must coincide with the vulnerable moment of systole. In the case of fibrillation which occurs spontaneously during coronary occlusion, the stimuli must originate in the heart. Now, it is well known that interruption of blood supply to an area causes the development of centers emitting occasional electrical impulses that are very much like brief induction shocks. This is proved by the frequent occurrence of premature systoles after coronary occlusion both in experimental animals and in man. According to our conception, fibrillation would result if one such spontaneously developed stimulus fell during the vulnerable period of a normal beat or that of a premature beat induced by discharge from another center. In addition to its proper incidence, the spontaneous stimulus must also be strong

enough. This is probably not the case when the myocardium is normal. However, we have found very recently that lack of blood supply greatly increases the irritability of myocardium, so that a very weak artificial shock suffices to cause fibrillation. We therefore believe that a natural electrical impulse discharged at the proper moment is sufficient in strength to fibrillate both ventricles when the tissue is hyper-irritable as a result of myocardial anemia.

Revival of Fibrillating Ventricles

A considerable mortality from ventricular fibrillation due to coronary occlusion and to accidental electrocution resulting from defects in electrical appliances or their improper use, has stimulated scientists to seek practical means for defibrillating the ventricles and restoring normal beats. However, the present state of achievement owes quite as much to fundamental discoveries made during the course of other investigation as it does to experiments designed particularly for this purpose.

Older investigators had clearly demonstrated that the ventricles of all animals are not equally susceptible to fibrillating agents. Fibrillation is difficult to induce in cold-blooded hearts but easily produced in those of mammals. The ventricles of many smaller mammals, such as mice, rats, cats, rabbits, hedgehogs and monkeys frequently recover spontaneously; whereas the ventricles of guinea pigs, dogs, sheep, goats and man do so rarely, if at all. Hence, the fatal nature of the process in animals which do not recover spontaneously was formerly stressed. The conception that such ventricles can not be defibrillated was soon shown to be erroneous, for it was proved that it could be stopped in excised hearts through cooling or cutting the muscle into smaller pieces. Admittedly, a wide hiatus exists between such abolition of fibrillation in excised hearts and the revival of hearts in the body. Nevertheless, these fundamental demonstrations served their purpose in recreating the hope that methods for resuscitation of such hearts might be discovered.

The experiment of Hering, a German physiologist, consisting in the abrogation of fibrillation in the perfused heart by addition of potassium chloride and the restoration of vigorous normal beats through subsequent irrigation with Locke's solution has frequently been repeated in physiological laboratories. It was therefore natural for investigators to employ this agent to check fibrillation of hearts within the body. Since the natural circulation is discontinued, the problem arose of devising means for transferring a potassium solution to every unit of fibrillating muscle and for removing or neutralizing it with calcium chloride after fibrillation had ceased. D'Halluin, a Belgian physiologist, reported success in 1904 from injecting potassium chloride solution into a jugular vein and spreading it through the myocardium by massage. In 1929, Hooker of Johns Hopkins University succeeded in reviving fibrillating ventricles by forcing a weak solution of potassium chloride into a carotid artery under pressure, while I stopped fibrillation by injecting stronger solutions directly into the ventricular cavities. Subsequent application of a calcium chloride solution by the same methods sometimes revived spontaneous beats.

While such occasional revivals constituted a technical achievement of which we were once justly proud, they were certainly inadequate. Looking back, they served their chief and broader purpose, not in their practicability, but in defining more clearly the requirements for successful revival. These seem to be (1) that every vestige of fibrillation disappears, (2) that adequate centers survive for the generation of spontaneous impulses, (3) that not too many and preferably only one center exists and (4) that the muscle fractions excited from

that center are capable of responding with vigorous contractions. As we review our experiments in which potassium and calcium were successively employed, we are not surprised that failures frequently occurred; it is rather remarkable that success was experienced so often. Potassium ions unquestionably abolish fibrillation, but they depress contractions and pacemakers as well. Subsequent use of calcium ions enhances contractions but it awakens so many centers of excitation that the ventricles easily revert to fibrillation. This is also a drawback to the use of adrenalin—a powerful cardiac stimulant so often used by surgeons to encourage revival of the heart.

A significant advance in resuscitation of the fibrillating ventricles occurred with the demonstration by Hooker and his associates in 1933 that a strong alternating shock, not more than 5 seconds in duration, abolishes fibrillation and restores normal beats. These investigators were not pioneers in the use of the method of countershock, but, as is often true in science, the greater credit belongs to those who place a discovery on a substantial foundation and give it currency in scientific thought. These investigators also showed that fibrillation of the heart in the closed chest can likewise be abolished by sending a strong countershock current through the heart by electrodes applied to the chest. Williams and his associates at Columbia subsequently demonstrated the effectiveness of extremely strong shocks in rams, which are more nearly comparable in weight to man.

Unfortunately, the method has its limitations, which were clearly recognized by its discoverers. Revival rarely occurs when the ventricles have fibrillated more than two minutes. We discovered that when fibrillation follows coronary occlusion it is not effective even within this short time-span. In order to be practical even for experimental purposes, it was necessary to extend the possible period of revival. This we feel constituted our contribution to the problem. The change in technique which made this possible was slight, but the physiological basis which it involves is a broad one and was suggested by entirely unrelated experiments.

In the first place, we had observed that failure to revive the ventricles after two or more minutes of fibrillation was generally not due to difficulty in abolishing fibrillation but rather to the weak character of the coordinated contractions resumed. These feeble beats either ejected no blood or only insignificant quantities, arterial pressures failed to rise and the heart quickly became more hypodynamic or reverted to fibrillation.

Secondly, the discovery was made during our study of coronary occlusion that the area affected by ligation of a coronary branch rapidly lost its power of effective contraction. Thus, the idea began to dawn that the "two-minute time limit" for revival after fibrillation is due to a similar interruption of the coronary flow. Vigorous contractions can not occur in the absence of a supply of oxygenated blood. Consequently, when the ventricles are defibrillated by a countershock, the contractions are necessarily very feeble. It also became clear as to why the method seemed so ineffective in abolishing the spontaneous fibrillation developing after coronary occlusion; in such cases large sections of the myocardium have been deprived of their blood supply even before fibrillation has begun.

The indications were obvious; the myocardium must be supplied with oxygenated blood *while fibrillation continues and before a countershock current is applied.* This we did by manual compression of the ventricles, about 40 times per minute, so that their cavities are emptied each time. This process, called cardiac massage, causes a material elevation of arterial pressure and forces blood through the coronary arteries supplying the myocardium. During the year which has passed, we have made an-

other slight but material change. While the ventricles are being rhythmically compressed, the aorta is partly constricted with the fingers, so that a larger proportion of the blood squeezed from the ventricular cavities is forced through its walls by way of the coronary arteries which arise central to the digital constriction.

During the course of experimental work in which the heart is exposed, my associates and I have witnessed over 1,000 revivals in all kinds of fibrillation in dogs weighing up to 18 kilograms. Indeed, the procedure is now standard in the laboratory, and its routine use has contributed significantly to the successful completion of complicated experiments on the coronary circulation.

Occasionally, however, the method fails because one or several shocks are unable to defibrillate the ventricle completely. A small area may persist in fibrillation, and we are inclined to believe that the interventricular septum continues to fibrillate even when it is not apparent from surface observations of the heart. Apparently, in order to defibrillate the ventricles completely a shock must pass through every fraction of fibrillating tissue in sufficient strength. If the hearts are large or the electrodes are not properly placed, an effective current may fail to pass through certain parts. The deep internal interventricular septum is particularly protected. Various expedients have been tried to overcome this emergency. We have increased the size of electrodes and intensified the countershock current used without great success. Moreover, very strong currents often spread to the auricles and start their fibrillation, an undesirable feature when the ventricles do revive. Beck and Mautz, who have adopted our modification of the countershock method in the laboratory of experimental surgery, were particularly impressed with the difficulty of completely defibrillating hearts of large dogs. They found that injection of small doses of procaine into the ventricular cavities, previous to the use of massage and countershock, was apparently helpful in abolishing such residual areas of fibrillation. Unfortunately, this drug depresses muscular contractions and unless cautiously used prevents the resumption of vigorous beats. For this reason, we have questioned its value as an adjuvant to countershock.

In investigations during the past year, supported by the John and Mary R. Markle Foundation, the need arose for a method which would revive fibrillating hearts promptly, certainly and repeatedly, and which did not involve the use of drugs or chemicals. With the development of our view outlined above that the fibrillation process evolutes by causing reentrant excitations in more and smaller areas, the thought arose that the evoluting process might conceivably be reversed by a *rapidly repeated series* of A.C. shocks. In this way, larger and fewer fibrillating areas might again be formed. Eventually the longer circuits created might be completely interrupted and the fibrillation stopped *without the necessity of having the countershock current traverse the entire myocardium.* If this were true, weaker currents might be employed, defibrillation would be more certainly accomplished, and auricular fibrillation more generally avoided.

Extensive tests proved that this can be done by applying a succession of 3 to 7 brief A.C. shocks of about 1 ampere in strength, at intervals of about 1 second. Each shock appears to convert the fibrillation into a coarser type until a final shock results in complete arrest of the ventricles. We have called the procedure *serial defibrillation.* The advantages are: (1) an effective current does not need to traverse each fibrillating fraction; it acts by merging excitation rings, (2) the ventricular septum, difficult to reach in larger hearts, is defibrillated, (3) weaker currents which are not so apt to start auricular fibrillation and have no after-effects on the ventricles can

be used, and (4) the certainty of recovery is increased. So far, the method has proved remarkably successful. During six months trial, tabulations of 328 tests showed only a single failure. Indeed, we now regard death from fibrillation in dogs whose hearts are exposed as evidence of negligence or bad technique.

The practicability of the countershock method in cases of human ventricular fibrillation due to electric shock or coronary occlusion naturally deserves careful consideration. It appears to us that, while we seem to be on the threshold of success, formidable barriers are blocking that threshold. These must be frankly recognized, for it is as important to emphasize the limitations of new discoveries as it is to herald their success. Only a few of the difficulties which confront us can be discussed in the space available. The practical utilization of the countershock method is thwarted by the difficulty of utilizing currents which are adequate to defibrillate the human heart. It is exceedingly doubtful whether 110 volts A.C. house current generally available, can yield sufficient current to defibrillate larger human hearts even when electrodes are applied directly. In rams, somewhat comparable in size, Spencer, Ferris, King and Williams found it necessary to use 3,000 volts giving currents of 25–30 A. in order to achieve defibrillation through electrodes applied to the chest. The danger to patient and operator alike—not to mention their general availability—is apparent. Our observations that weaker serial shocks seem to be efficacious, reawakens the hope that this procedure may require less current for revival of human fibrillating hearts. Unfortunately, the difficulty does not end here. Any method of countershock employed by itself must not be expected to be effective beyond two minutes of fibrillation and perhaps less. To rush a patient to a hospital, institute artificial respiration, open the chest aseptically and massage the heart within 15 minutes requires a degree of optimism which physiologists find it difficult to share with surgeons. This, however, is certainly the maximum interval after which revival of brain function can be expected; indeed, it is highly probable that mental deterioration would occur within a much shorter period of complete cerebral anemia.

For the present, the hope for revival is apparently restricted to patients who develop fibrillation on the operating table, and particularly those in whom the heart has already been exposed. Prompt utilization of massage and serial countershock should prove effective in such cases. To meet such contingencies, cardiac surgeons generally will probably soon follow the lead of Dr. Beck of our surgical department in adding appropriate countershock apparatus as standard equipment in their operating rooms.

We see little prospect that revival methods so far developed will have great prospect of success in restoring hearts that fibrillate as a result of coronary thrombosis. Experimentation has shown clearly that such hearts can not be revived unless the occlusion is first removed and the ischemic area flooded with arterial blood by massage; two conditions difficult to realize in man. While the revival of human hearts from fibrillation must not be regarded as hopeless, we must not allow ourselves or others to become too optimistic. Indeed, it seems more profitable for the present to direct research talents toward the task of attempting to render the heart less sensitive to fibrillating agents or even better of making it completely refractory.

Sensitization and Desensitization of the Ventricles to Fibrillation

The literature contains a number of experimental reports which support the general belief that the tendency of the ventricle to fibrillate can be increased or decreased by nervous or humoral agents as well as by certain drugs. The results of our studies indicate, however, that this has not been demonstrated as

critically as investigators generally believe. Space is lacking to do more than enumerate the types of studies upon which such conclusions are based. They are:

1. Comparison of time elapsing between coronary occlusion and the incidence of fibrillation, —a very variable period according to our experience.
2. Determination of differences in strengths or durations of a current required to induce fibrillation; a very erratic method, because any current which lasts more than .05 second creates a number of factors which may induce fibrillation fortuitously.
3. Comparisons of the durations of fibrillation in the cat; a very variable interval according to our experience and that of others.

That such tests are inadequate is indicated also by the contrary effects imputed to the same agents or processes by different investigators. Thus, activity of the accelerator nerves or adrenalin is claimed both to increase and to decrease the resistance of the ventricles to various fibrillating agents.

We have only recently suggested a new criterion based on our proof that fibrillation is due to application or release of an effective stimulus during the vulnerable phase of the systole. It consists in measuring the resistance of the ventricles to fibrillation—or tersely, the fibrillation threshold—by the strength of a brief shock which, applied during the vulnerable period, just suffices to fibrillate. We believe that it takes into account the irritability of responsive muscle fibers and the eventual additional state which determines that the premature impulses reenter and begin to circulate.

Many technical and experimental details need to be overcome, however, before such a simple test could be put into practice. The most suitable, and easily measurable, electric shock had to be decided upon. Special apparatus had to be designed in order to apply such shocks with certainty to an occasional vulnerable period. After considerable experimentation we chose the milliampere value of rectilinear shocks .01 to .03 second in duration, which, when applied during the vulnerable period, induced fibrillation, as a measure of the fibrillation threshold. By applying our method of defibrillation, repeated tests could be made on the same animal before and after treatment.

Since the determination of each threshold required 30 minutes, and the effects of a drug could not be determined in less than 5 or 6 hours, it was necessary to determine how constant the threshold remained after successive defibrillations over such a long period. It was in fact at one time feared that the alterations in pressure and chemistry of the blood, or the effects of countershock currents on the fibrillation process itself might prevent use of this mode of testing. Indeed, most of our time was spent in discovering the factors which yield inconstant threshold values and in inventing ways in which to avoid or circumvent them. Among the factors we have learned to control are the temperature of the ventricular surface, the careful placement of electrodes on the same spot, the avoidance of polarization and other effects of repeated currents, etc. In addition, it proved necessary to revive the ventricles quickly from each fibrillation and to allow an equilibration period not less than 15 minutes after each recovery before making another test.

With attention to these and other numerous details, we have evolved a procedure by which reasonably constant fibrillation thresholds can be obtained over a period of five or six hours in untreated dogs. Employing this method, we succeeded in showing that the fibrillation threshold is tremendously reduced during coronary occlusion, and that procaine tends to raise the threshold. The procedure is now perfected so that the actions of many drugs and physiological influences can be tested in a systematic manner.

THE PRESS IN AMERICAN CITIES[1]

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WHAT is an American newspaper? How do the newspapers in cities that rank high in welfare differ from those in cities that are, relatively, low in welfare?

To answer these questions, a count was made of the amount of space (excluding advertisements) given to each of the topics listed below in one or more issues of one or more newspapers for the six week days, September 13 to 18, 1937, in Augusta (Ga.), Berkeley, Birmingham, Charleston (S. C.), Chester, Colorado Springs, Columbus (Ga.), East St. Louis, Evanston, Glendale, Grand Rapids, High Point, Kalamazoo, Lewiston (Me.), Manchester, Meridian, Minneapolis, Mobile, Oakland, Pasadena, Rome (N. Y.), San Diego, San José, Santa Barbara, Seattle, Springfield (Mass.), Tucson and Woonsocket. In all, 135 issues of newspapers were inventoried. The topics were: (1) foreign news: war; (2) foreign news: not war; (3) education: general U. S.; (4) education: local; (5) art: general U. S.; (6) art: local; (7) music: general U. S.; (8) music: local; (9) crime: general U. S.; (10) crime: local; (11) local society, clubs, etc.; (12) local personal items; (13) athletics and sports; (14) radio programs; (15) science; (16) intelligence tests; (17) bridge; (18) cross-word puzzles; (19) question-answer; (20) stories; (21) story pictures; (22) comic strips; (23) cartoons; (24) weather; (25) stocks and bonds; (26) commodities.

We compute for each city the percentage which the space accorded to each of these topics is of the space accorded to them all. There is a considerable variation among the 28 cities in almost every one of these percentages. To reduce the influence of special local events, we take only the 24 cities for which records of three or more days of the week, including at least one day from each half of the week, are available. The spread in percentage required to include two thirds of these 24 cities are as follows:

Foreign, war: 7.3 down to 3.3, a ratio of 2.2 to 1.
Foreign, not war: 4.3 down to 2.0, a ratio of 2.1 to 1.
Education, art and music, general: 2.0 down to .4, a ratio of 5 to 1.
Education, art and music, local: 2.35 down to .51, a ratio of 4.6 to 1.
Crimes outside the neighborhood: 2.4 to .75, a ratio of 3.2 to 1.
Local crimes: 1.9 to .65, a ratio of 2.9 to 1.
Local associations, clubs, society and personal items: 14.8 to 7.6, a ratio of 2.1 to 1.
Athletic sports and games: 33.6 to 22.55, a ratio of 1.5 to 1.
Radio programs: 5.05 to .73, a ratio of 6.9 to 1.
Science: .70 to .105, a ratio of 6.7 to 1.
Intelligence tests: .10 to 0.
Contract bridge lessons, problems, etc.: a ratio of 1.15 to 0.
Cross-word puzzles: .265 to .13, a ratio of 2 to 1.
Questions and answers: 3.80 to .57, a ratio of 6.7 to 1.
Stories: 7.3 to 3.7, a ratio of almost 2 to 1.
Story pictures: 8.35 to 2.55, a ratio of 3.3 to 1.
Comic strips: 16.7 to 8.15, a ratio of 2 to 1.
Cartoon: 6.1 to 2.8, a ratio of 2.2 to 1.
The weather: 1.65 to .48, a ratio of 3.4 to 1.
Stocks and bonds: 11.4 to 1.7, a ratio of 6.7 to 1.
Commodity markets: 4.6 to .75, a ratio of 6.1 to 1.

What do the differences in the contents of the newspapers of cities signify? In particular, how are they related to the quality of the population and its life? I have determined for each city a score, G, for the general goodness of life for good people, which is a weighted average of the thirty-seven items listed below. Fourteen of the cities were chosen for the investigation because they ranked at or

[1] The investigation reported in this article was one small part of a project supported by a grant from the Carnegie Corporation.

near the top of the 310 cities in the United States having 30,000 or more population in 1930. Fourteen were chosen because they ranked at or near the bottom in this G score.

CONSTITUENTS OF THE G SCORE OR INDEX

Items of Health

Infant death-rate reversed; General death-rate reversed; Typhoid death-rate reversed; Appendicitis death-rate reversed; Puerperal diseases death-rate reversed.

Items of Education

Per capita public expenditures for schools; Per capita public expenditures for teachers' salaries; Per capita public expenditures for textbooks and supplies; Per capita public expenditures for libraries and museums; Percentage of persons sixteen to seventeen attending schools; Percentage of persons eighteen to twenty attending schools; Average salary, high-school teacher; Average salary, elementary school teacher.

Items of Recreation

Per capita public expenditures for recreation; Per capita acreage of public parks.

Economic and "Social" Items

Rarity of extreme poverty; Rarity of less extreme poverty; Infrequency of gainful employment for boys 10–14; Infrequency of gainful employment for girls 10–14; Average wage of workers in factories; Frequency of home ownership (per capita number of homes owned); Per capita support of the Y. M. C. A.; Excess of physicians, nurses and teachers over male domestic servants.

Creature Comforts

Per capita domestic installations of electricity; Per capita domestic installations of gas; Per capita number of automobiles; Per capita domestic installations of telephones; Per capita domestic installations of radios.

Other Items

Per cent. of literacy in the total population; Per capita circulation of *Better Homes and Gardens*, *Good Housekeeping* and the *National Geographic Magazine*; Per capita circulation of the *Literary Digest*; Death rate from syphilis (reversed); Death rate from homicide (reversed); Death rate from automobile accidents (reversed); Per capita value of asylums, schools, libraries, museums and parks owned by the public; Ratio of value of schools, etc., to value of jails, etc.; Per capita public property minus public debt.

The cities at or near the top were: Berkeley, Colorado Springs, Evanston, Glendale, Grand Rapids, Kalamazoo, Minneapolis, Oakland, Pasadena, San Diego, San Jose, Santa Barbara, Seattle and Springfield (Mass.). The cities at or near the bottom were: Augusta, Birmingham, Charleston (S. C.), Chester, Columbus (Ga.), East St. Louis, High Point, Lewiston, Manchester, Meridian, Mobile, Rome, Tucson and Woonsocket.

I have also for each city a score, P, for the personal qualities of its population, which is a weighted average of the eleven items listed below. The fourteen cities high in G were on the average very high in P also; and the fourteen low in G were on the average very low in P.

Per capita number of graduates from public high high schools in 1934; Percentage which public expenditures for the maintenance of libraries was of the total public expenditures; Percentage of illiteracy (reversed); Percentage of illiteracy among those aged 15–24 (reversed); Per capita circulation of public libraries; Per capita number of homes owned; Per capita number of physicians, nurses and teachers minus male domestic servants; Per capita number of telephones; Number of male dentists divided by number of male lawyers; Per capita number of deaths from syphilis (reversed); Per capita number of deaths from homicide (reversed).

I make the comparison by two methods. By the first method each city is given equal weight with every other; by the second, any one day's issue of any newspaper is given equal weight with any other. The figures are always for percentages of space given to the topic in question. Each percentage has as its base the total space given to all the topics of our list.

Table I relates how the press of the cities ranking high in G and P (the scores for general welfare and for qualities of intelligence, morality, etc.) divided the space which it accorded to the 23 items; and similarly for the press of the cities ranking low in G and P.

The greatest difference was in the case of intelligence tests, to which the press in superior cities gave over three times

as large a fraction of the space. The next greatest difference was in the stock-exchange reports, which had two and a half times as large a fraction of the space in the superior cities. The next concerned radio programs. The next two concerned local crime and the game of bridge to which the press in high cities gave less than two thirds as much of the total allotment as the press in low cities did.[2] General crime comes next.

The newspapers in the cities low in G and P furnish less information and more sheer entertainment, the percentage for stories, story-pictures and comic strips combined being almost 26 for them and under 20 for the high cities.

due largely to scientific treatment of water, milk, etc., is about twice as great in the low fourteen, but the per cent. of space given to facts of science is almost the same. The per capita circulation of public-library books is only one third as great in the low cities as in the high, and the per cent. of 16- or 17-year-olds attending public schools is about half as great. But the per cent. of space given education, art and music is about the same, the newspapers of the low cities giving in fact somewhat more space. There are only one fourth as many radio sets per thousand population, but radio programs occupy over half as large a fraction of the space.

TABLE I

COMPARISON OF 14 CITIES VERY HIGH IN G (GENERAL GOODNESS OF LIFE FOR GOOD PEOPLE) AND P (PERSONAL QUALITIES OF THE POPULATION) IN RESPECT OF THE PERCENTAGE OF NON-ADVERTISING SPACE USED FOR VARIOUS TOPICS

Topic	Average percentages and ratios					
	Weighting each city as 1			Weighting each issue as 1		
	A Cities high in G and P	B Cities low in G and P	A/B Ratio	A Cities high in G and P	B Cities low in G and P	A/B Ratio
1. Foreign news: war	5.4	6.1	.89	4.3	5.6	.76
2. Foreign news: not war	2.8	3.6	.79	2.4	3.4	.70
3. Education, art and music: not local	0.96	1.22	.78	.76	1.23	.62
4. Education, art and music: local	1.85	1.47	1.26	1.60	1.60	1.00
5. Crime: not local	1.46	1.99	.73	1.33	2.03	.66
6. Crime: local	1.19	1.88	.63	1.21	1.85	.65
7. Local society, clubs, organizations	6.9	5.3	1.30	6.6	5.5	1.21
8. Local personal items	4.9	5.2	.94	4.7	5.2	.89
9. Athletic sports and games	27.5	26.5	1.04	30.4	27.9	1.09
10. Radio programs	4.4	2.4	1.84	4.4	2.4	1.88
11. Science	0.37	0.34	1.11	0.40	0.40	1.00
12. Intelligence Tests	0.18	0.03	6.23	0.07	0.03	2.33
13. Contract bridge lessons, problems, etc.	0.46	0.60	.77	0.37	0.75	.49
14. Cross-word puzzles	1.68	2.26	.74	1.52	2.19	.69
15. Questions and answers	2.38	2.33	1.02	2.01	2.44	.82
16. Stories	4.0	6.0	.66	4.0	5.9	.68
17. Story-pictures	5.2	6.6	.78	4.5	6.3	.71
18. Comic strips	10.9	13.4	.81	10.4	13.1	.79
19. Cartoons	5.0	4.7	1.06	4.3	4.5	.94
20. Weather	1.52	0.93	1.64	0.94	0.81	1.16
21. Stock and bond markets	8.5	3.6	2.37	10.3	3.9	2.67
22. Commodity markets	3.2	2.8	1.15	3.6	3.1	1.16

On the whole the differences between the high and the low cities are of the character that would be expected *a priori*, but are very small. The number of deaths from homicide per thousand population in the low fourteen is about five times as great as that in the high fourteen, but the per cent. of space given to crime news is only 1½ times as great. The infant death rate, decreases in which are

The press in the low cities does not emphasize local society and personal items at the expense of foreign non-war news. It is extremely unlikely that the general news not included under our rubrics, and the editorials and other comments on the news, would show greater differences in content than our counts show. They probably would show smaller differences.

It is possible that the detailed quality of the contents of the newspapers would

[2] High and low mean, of course, high in G and P and low in G and P.

have shown greater differences than our counts showed. The newspapers of the superior cities may be more truthful, intellectual, moral, humane, refined and impartial than the others to a degree not shown by the counts of subject-matter. Such a qualitative analysis requires much time from very able critics and was impossible within my resources. But such casual inspection as I could make leads me to expect that these differences also are rather small. There certainly were many editorials in the press of the low cities which were excellent in every way. It must also be kept in mind that much of the contents of the press in all these cities is bought from agencies and used as bought.

The variations among cities in the contents and style of the press are very great, but they seem to be caused largely by local customs and the ideas of owners and editors, rather than by fundamental differences in the ideals of the residents. The press of a city is in fact not an accurate indicator of its general degree of civilization, welfare, humaneness or intelligence. There is a correlation, but it is not close. One glance at the infant death rate, the percentage of 16- and 17-year-olds in school, the per capita circulation of public-libraries, and the number of telephones per thousand population will give a truer picture of the quality of life in a community than a perusal of ten thousand columns of its newspapers. A newspaper is not a mirror reflecting the nature of the community where it is published. Nothing short of a solid body of facts can do that. On the contrary, the newspaper in any of these twenty-eight cities could probably change its content to be more like the average newspaper without losing much circulation or causing much criticism or even having the changes noticed, if it made them slowly enough. Indeed, a sordid commercialism could find moderate support for its kind of newspaper in our "best" cities; a competent idealism could find support for its kind of newspaper in our "worst" cities. The profiteer and the enthusiast would probably fill their papers with much the same content—namely, that which the buyers of newspapers expect to find in newspapers. In judging a community, its newspaper should be considered, but only as one among scores of features of its life.

It is common to speak of the newspapers of to-day as purely commercial enterprises managed with an eye single to profits, which are to be got from advertising, which is to be got by circulation, which is to be got by entertainment for the masses, which is to be got by avoiding all intellectual difficulties and appealing to common passions and prejudices. The facts of the counts suggest that for most of the press of the United States, this is a slander. It would be truer to say that the newspaper of today, with considerable disregard of the cravings of the populace, provides a conventional mixture of facts about what has happened during the past twenty-four hours at home and abroad, descriptions of athletic contests, statistics about prices, fiction and humor in words and pictures, and notes about women's styles, housekeeping, politics, personal health and happiness, and occasionally about the impersonal world of truth and beauty. The departures from this conventional mixture either upward toward what the ablest and best would choose in their noblest moments or downward toward what the dull and vulgar seek as entertainment, are few and slight.

Apparently those who buy newspapers still in large measure buy them not as a means of entertainment in competition with the movies, the radio, gambling, eating, drinking, sex-indulgence, etc., but mainly for the conventional features of a newspaper of the past half century. Those who make newspapers apparently still in large measure consider their craft to be that of getting and presenting news, and not an apprenticeship for pictorial magazines, Hollywood or television.

SYNTHETIC RUBBER

By Dr. B. S. GARVEY, JR.
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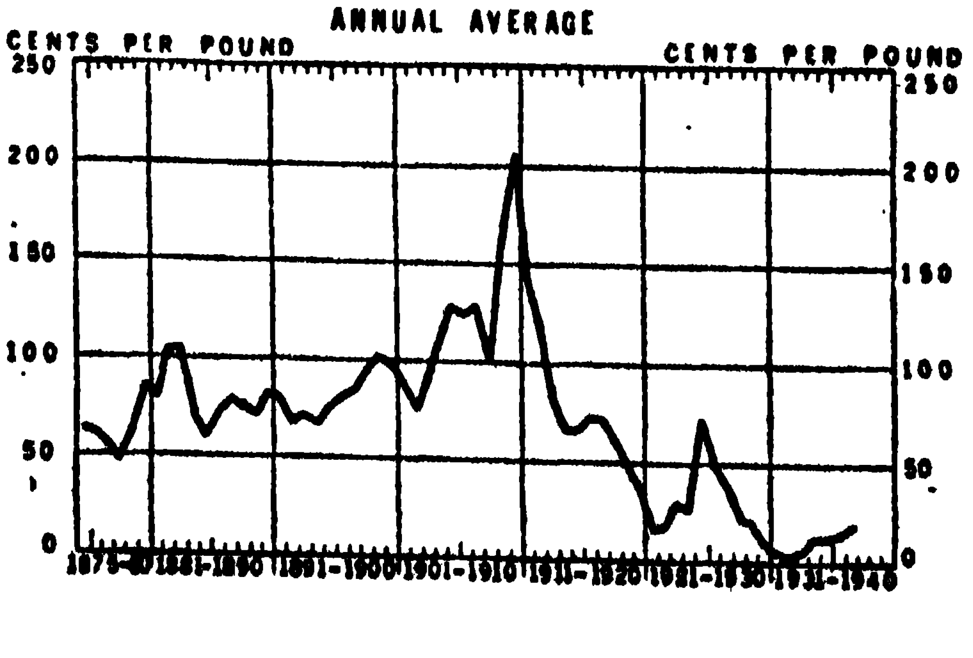
Introduction

No material has ever been synthesized which is identical with natural rubber in the same sense that synthetic indigo is identical with natural indigo. The early experiments were attempts to make such a duplicate of natural rubber, and for nearly fifty years this synthesis has been one of the aims of organic chemists. What we call synthetic rubbers are materials which resemble rubber in physical properties but which differ by varying degrees in chemical composition. The development of these materials has been influenced by the supply and price of crude rubber, by political conditions and by increasing knowledge of rubber and other high molecular materials.

World production and United States prices of crude rubber since 1880 are shown in the following two charts taken from "Rubber Statistics," published by the U. S. Department of Commerce in 1938.

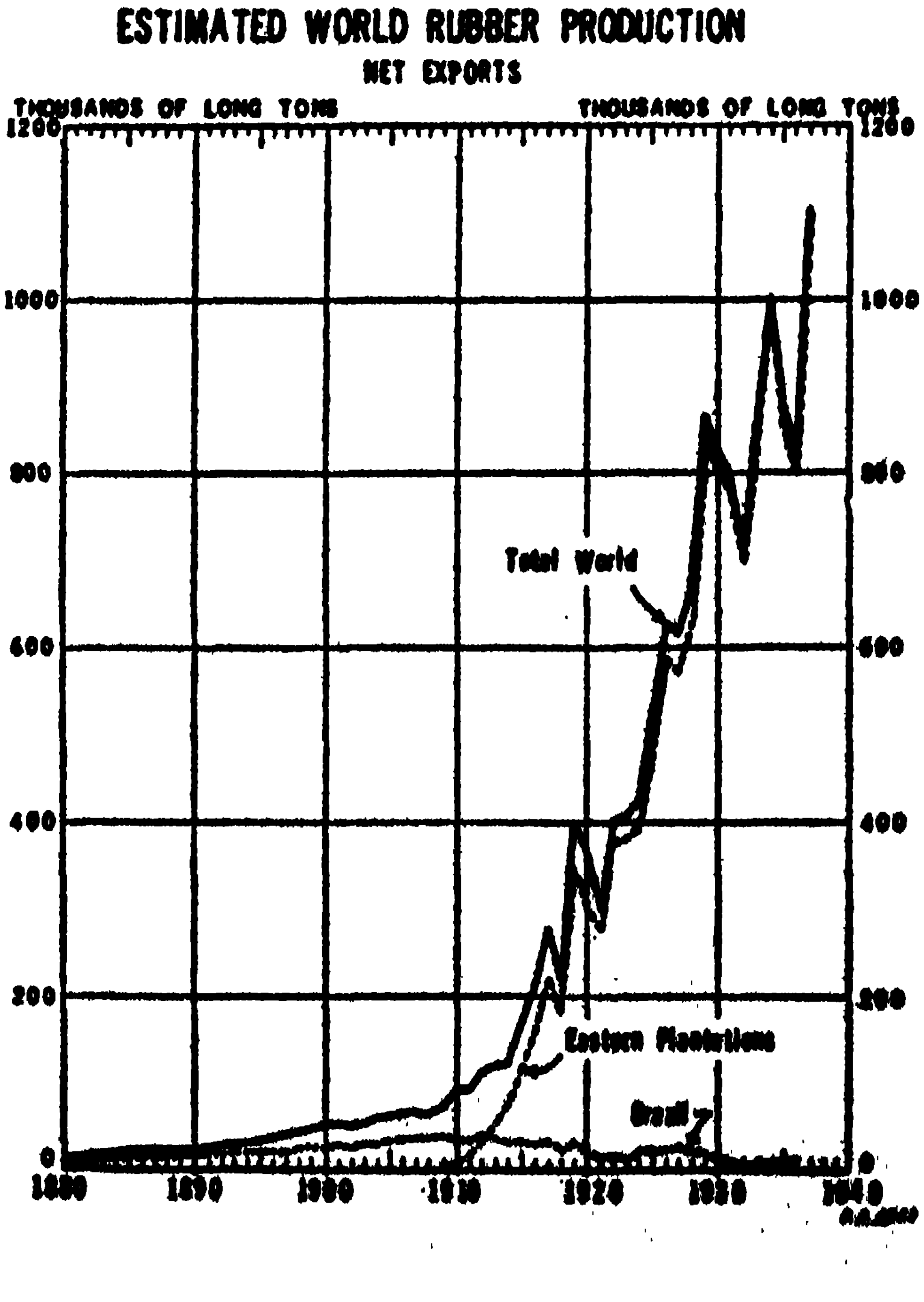
"Popularity of the bicycle and the demand for rubber tires brought about the high prices in the 1890's; and, similarly, the automobile and the Brazilian scheme for the valorization of rubber were directly responsible for the high prices of 1905 to 1910." These high prices caused a ruthless exploitation of all sources of wild rubber, especially in Africa and Brazil, and led to an increasing use of reclaim, although it is inferior to crude rubber. A few years after Tilden first polymerized isoprene, in 1891, the boom in rubber prices changed the primary objective of research from one of scientific duplication to one of commercial production of a technical equivalent. At the same time the infant plantation industry of the Far East was greatly stimulated. By 1917 there was an adequate supply of cheap, high-grade plantation rubber. For several years after this there was little interest in synthetic rubber.

U. S. CRUDE RUBBER MARKET PRICES



The World War demonstrated the military importance of rubber, and in recent years an assured supply of rubber, natural or synthetic, has become a matter of vital concern to all govern-

ESTIMATED WORLD RUBBER PRODUCTION



ments. For countries which are subject to blockade, like Germany and Russia, this has meant intensive, subsidized work on a synthetic replacement for natural rubber.

The accumulation of knowledge concerning polymers and polymerization has resulted in the production of two types of rubber-like materials which can compete with rubber in a free market because, in addition to the desired physical characteristics of the natural product, they have advantages which justify a higher cost.

The synthetic rubbers, Neoprene and Perbunan (Buna N), are diene polymers which yield compositions more resistant to oil and to aging under severe conditions than does natural rubber. Materials like Thiokol, Koroseal and Vistanex are flexible and elastic, although in chemical composition they are fundamentally different from natural rubber.

The Duplication of Natural Rubber

As far back as 1826 Faraday showed that the chemical composition of rubber can be expressed by the formula C_5H_8. In 1860 Williams obtained isoprene, $CH_2=\overset{\overset{\textstyle CH_3}{|}}{C}-CH=CH_2$, by the destructive distillation of rubber, and in 1891 Tilden showed that it would polymerize on standing to a rubber-like product. Later investigators have demonstrated that the rubber hydrocarbon is a polymer[1] containing at least eight and probably several hundred C_5H_8 groups arranged end-to-end in the general structure $(-CH_2-\overset{\overset{\textstyle CH_3}{|}}{C}=CH-CH_2-)x$.

[1] A polymer is a large molecule made by the combination of many small ones. If we consider a dish of ordinary paper clips as molecules of isoprene, we can string them all together as a chain which would correspond to a rubber molecule. Forming the chain is roughly analogous to polymerization and the chain to a polymer.

For a number of years investigators of many nations sought methods of making isoprene and methods of polymerizing it to rubber. The most satisfactory preparations were by the destructive distillation of rubber and the thermal cracking of terpenes. Isoprene so prepared would polymerize on long standing at room temperature. The polymerization could be hastened by heating, exposure to light or by the use of catalysts such as the peroxides or metallic sodium. The products of such polymerizations were not of industrial significance because of the cost of isoprene. Furthermore, they differed chemically from natural rubber, did not process well, gave vulcanizates of poor physical quality,[2] and were not technically equivalent to it. Their behavior on aging was bad both before and after vulcanization.

When one considers the complexity of the problem it is not surprising that the aim of the first era was not reached at that time, nor has it yet been realized. In the first place, natural rubber, in addition to the rubber hydrocarbon, contains 5 to 10 per cent. of non-rubber constituents. Among these we now know are substances with profound effect on the aging and vulcanizing characteristics of the rubber. The hydrocarbon itself appears to be a high polymer of the composition $(-CH_2-\overset{\overset{\textstyle CH_3}{|}}{C}=CHCH_2-)x$ in which the methyl groups are symmetrically placed along the chains and in which the geometrical configuration at each double bond is the same (it is geometrically homogeneous). With regard to double bonds, isoprene

[2] Crude rubber is tough, thermoplastic, and hardens at about 0° C. When masticated on a rubber mill it becomes soft, plastic, tacky or sticky, soluble and easy to process. Vulcanized rubber is non-thermoplastic, very tough and strong, non-tacky and insoluble. It is elastic from −50° C. to well above 100° C.

$$\underset{1}{CH_2} = \underset{2}{\overset{\overset{CH_3}{|}}{C}}-\underset{3}{CH} = \underset{4}{CH_2}$$

can polymerize in four ways: 1–4, 1–2, 3–4, and 1–2 and 3–4. Along the chain it may polymerize head to head or head to tail

$$(-\underset{1}{CH_2}-\underset{2}{\overset{\overset{CH_3}{|}}{C}} = \underset{3}{CH}\underset{4}{CH_2}\underset{1}{CH_2}\underset{2}{\overset{\overset{CH_3}{|}}{C}} = \underset{3}{CH}\underset{4}{CH_2}-)$$

or

$$(-\underset{1}{CH_2}\underset{2}{\overset{\overset{CH_3}{|}}{C}} = \underset{3}{CH}\underset{4}{CH_2}\underset{4}{CH_2}\underset{3}{CH} = \underset{2}{\overset{\overset{CH_3}{|}}{C}}\underset{1}{CH_2}-).$$

If both 1–2 and 3–4 polymerizations take place, the chain may become branched or cross links may be formed between chains. Even if the polymerization be all 1–4 and head to tail, the individual double bonds may have either a cis- or a trans configuration. The polymerization must be further controlled so that the molecular weight falls in the right range. Finally suitable chemicals must be added to act as preservatives and vulcanizing aids.

The Production of a Replacement for Natural Rubber

The second phase of the work was concerned largely with the investigation of 1–3 dienes, which might be prepared economically and which would polymerize to give useful products. A measure of success along this line made necessary the use of accelerators and age resistors, a development which subsequently became of prime importance in the use of natural rubber.

The two dienes with best commercial prospects were found to be butadiene 1–3 and 2–3 dimethyl butadiene 1–3. The former could be obtained by the dehydration of 1–3 butylene glycol, and in small yields by the cracking of hydrocarbon oils. In no case, however, was low production cost realized. Dimethyl butadiene was made by the dehydration of pinacol which, in turn, was made from acetone. Processes and yields were fairly satisfactory, but the cost was high.

The synthetic rubbers made by the polymerization of these dienes were of poor quality and were more nearly comparable to reclaims than to crude natural rubber. As a result they had no large-scale development prior to the World War. Under pressure from the British blockade the Germans were forced to extraordinary efforts and put into production the synthesis of dimethyl butadiene and its polymerization. Several hundred tons of methyl rubber were made. In addition to the poor qualities it shares with the butadiene polymers, this rubber has the added disadvantage of becoming hard and of taking a high set in ordinary cold weather. Hence it was often necessary to jack up the wheels when trucks were left standing outdoors in cold weather.

After the war the large supply of cheap, high-grade, plantation rubber discouraged the development of the synthetic material, especially because of the poor quality of the latter. There was very little development in this field over the next decade.

Some time in the later nineteen twenties, the synthetic rubber problem was reopened, this time by two of the world's largest chemical companies, the I.G. in Germany and du Pont in America. The German work has resulted in the Buna rubbers and the American work in Neoprene.

In Germany the first step was a review of the various butadienes to select the most satisfactory one from the standpoint of quality of the polymer, availability of raw materials and economy of manufacture. Butadiene was selected. The starting material is coal, which is heated with limestone to make calcium carbide. With water this gives acetylene, and this in turn adds a molecule of water to give acetaldehyde. The aldehyde is condensed to aldol. These three

reactions are old and had been well developed. The aldol is then catalytically hydrogenated to 1–3 butylene glycol and this is catalytically dehydrated to butadiene. While there are a number of steps in this reaction, the over-all yield is good and the raw materials are available in Germany. In a modification of this procedure ethyl alcohol, from any source, is dehydrogenated to acetaldehyde. The aldehyde is converted to aldol, which is hydrogenated with the hydrogen removal from the alcohol. In the United States the most economical source of butadiene is petroleum or natural gas, from which it can be made by cracking or dehydrogenation processes.

The first products of the I.G. were made by polymerizing liquid *bu*tadiene with sodium (*Na*). Hence the name Buna. Like the pre-war products, these were of poor quality. In an effort to improve the quality of the rubber, the polymerization of butadiene was performed in aqueous emulsion. It was soon found that the addition to the butadiene of other polymerizable materials modified the polymerization and greatly improved the quality of the product. As a result of this work there are at present two principal types of Buna. Buna S is a mixed polymer of butadiene and styrene, while Buna N, or Perbunan, is a mixed polymer of butadiene and acrylic nitrile. Both are made by controlled polymerization in emulsion.

Buna S is considered primarily as a substitute for natural rubber in tires, belts, etc. It is more difficult to process than natural rubber, but with suitable precautions can be handled on essentially the same machinery. It has little "tack," the quality of natural rubber which makes two pieces coalesce when pressed together. This makes building operations difficult. The vulcanizates, however, are of a quality comparable with natural rubber. For tire treads Buna S is as good as, or better than, natural rubber. For pure gum compounds, such as rubber bands, it is much worse. The difference is due to the great reinforcing action of carbon black on Buna. Buna S is cheaper than Buna N because styrene is cheaper than acrylonitrile. Hence Buna S was selected for large-scale production in Germany.

The Development of Improvements on Natural Rubber

With Buna N and Neoprene we come to the third phase of synthetic rubber development. Buna N, like Buna S, can with certain limitations be used as a substitute for natural rubber. In addition it has certain great advantages. It is but little affected by petroleum hydrocarbons and is much more resistant to heat than natural rubber. Consequently, it can be used satisfactorily under hot and oily conditions where rubber fails quickly. It has even better abrasion resistance than natural rubber. Like Buna S, it is difficult to process and lacks adequate building tack. However, it can be handled satisfactorily in factory operations.

The du Pont development started from the work of Nieuwland at Notre Dame on acetylene and led to the production of substituted butadienes. Two molecules of acetylene polymerize to form vinyl acetylene, which adds one molecule of hydrogen chloride to form chloroprene, $CH_2 = \overset{\overset{\displaystyle Cl}{|}}{C} - CH = CH_2$, a diolefine in which a chlorine replaces the methyl group in isoprene. While other substituted butadienes have been made and polymerized, chloroprene is the only one which has achieved commercial significance.

Under properly controlled conditions liquid chloroprene polymerizes to a rubbery polymer, similar to natural rubber and of use as a replacement for it in most cases. Like Buna N, it has impor-

tant advantages over natural rubber. It is resistant to the action of petroleum hydrocarbons and vegetable and animal oils. It is not sensitive to sunlight or corona discharge, and it will not continue to burn when ignited. Hence Neoprene can be used in many places where natural rubber can not. Unlike natural rubber or the Bunas, Neoprene is not vulcanized by sulfur, and hence a new technique of compounding had to be developed. Although special precautions are also necessary, it can be used in regular factory operations.

More recently the process for polymerizing chloroprene in emulsified form has been worked out. This permits smoother and more efficient production with resulting lower prices.

Russian Developments

Because of political and economic isolation, Russia was the first of the great nations to attempt autarchy; and because rubber is one of the few essential raw materials not available in Russia, a great deal of work was done on synthetic rubber, as well as on the cultivation of rubber-bearing shrubs similar to Guayule. It is known that in Russia butadiene is produced both from alcohol and from petroleum. Apparently this is converted principally to the sodium polymer. It seems probable that rubbers of the Buna type are also being made. It has also been reported that chloroprene is being polymerized to a material similar to Neoprene. Outside of Russia, however, little is definitely known about these Russian products.

Other Elastic Materials

There are several materials of fundamentally different chemical constitution which are sufficiently like rubber in physical properties to justify their inclusion in a discussion of synthetic rubber. All the previously discussed materials have been polymers or co-polymers of butadiene or substituted butadienes. Thiokol, Koroseal and Vistanex are elastic products derived from other basic molecules.

Thiokol. When ethylene dichloride is refluxed with an aqueous solution of sodium polysulfide a linear polymer is formed which is rubbery and which has the constitution

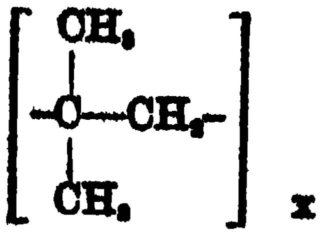
$$(-CH_2CH_2-S_x-CH_2-CH_2S_x-)y.$$

In place of ethylene dichloride, propylene dichloride, dichloroethyl ether or other dichlorides may be used. These materials were developed in America as Thiokol and in Germany as Perduren. They undergo a type of vulcanization, but the effect is not as pronounced as with rubber. Thiokol has a characteristic odor. With respect to tensile strength, toughness and cold flow it is not as good as the materials previously discussed, but it probably has better general solvent resistance. It was the first material of this group to be developed commercially.

Koroseal. The gamma polymer of vinyl chloride is extremely tough and is unique in the strength and toughness of the gels formed from it with various liquids. As Koroseal in this country and Igelite in Germany, these gels have become of great commercial importance. The polyvinyl chloride itself is resistant to nearly all chemicals and to most solvents. It does not burn or support combustion, and is practically unaffected by aging. By skilful compounding of plasticizers, pigments, etc., flexible and elastic gels can be obtained which retain, in large measure, these resistant characteristics. Koroseal need not be vulcanized. It can be tubed, calendered and molded thermoplastically. In addition to the rubbery types which are used for wire insulation, tank linings, special hose and tubing and molded parts, Koroseal can be made as a hard molding plastic, as transparent films for packaging, and as

a waterproof, greaseproof and age-resistant coating for all kinds of fabrics.

Vistanex. Vistanex is polymerized isobutylene of the probable structure



It combines to a considerable extent the physical properties of rubber and the chemical properties of paraffin. Like rubber it is a hydrocarbon, but unlike rubber it has no double bonds and therefore does not vulcanize. On a mill it does not become as plastic as rubber and it is therefore more difficult to process. Cold flow limits its use as a rubber substitute and it is used principally as a coating material. The lower polymers are extensively used in lubricating oils to reduce the fall in viscosity with rising temperature.

Recent Developments

During the year which has elapsed since the outbreak of the war in Europe there have been several announcements which show that extensive research programs have been under way for several years on the development of new synthetic rubbers. All the products recently announced use petroleum as the basic raw material and all appear to be some type of butadiene copolymer. Definite compositions have not been announced.

Buna. The Standard Oil Company of New Jersey has acquired the American patent rights relating to the manufacture of the Buna rubbers and has announced that it will start production of Perbunan late in 1940. The Firestone Tire and Rubber Company has taken a license under these patents and has announced plans for starting production.

Butyl Rubber. The Standard Oil Company has announced the small-scale production of "Butyl Rubber," which is a copolymer of olefins and diolefins. The proportion of diolefin is small so that the vulcanised product is essentially a saturated hydrocarbon. While no definite composition of the material has been reported, the description of its properties suggests that it is a Vistanex type made vulcanizable by the use of a small proportion of a diolefine. The high proportion of olefine in this rubber makes it different from the others. It is too early to do more than guess as to its place in the general picture.

Ameripol and Hycar. The Hydrocarbon Chemical and Rubber Company has announced the small-scale production of "Hycar O R" and is enlarging its plant for the manufacture of this material. There are two types of Hycar, one of which is oil resistant and other not. Both are butadiene copolymers of undisclosed composition. The B. F. Goodrich Company markets products made from Hycar under the general trade name, "Ameripol."

Ameripol tires made of Hycar are being sold to the public at a premium of about 30 per cent. above the cost of tires made of natural rubber. Experience indicates that these tires are equivalent in quality to the present tires of natural rubber. There are a number of minor differences in the production of tires when Hycar is used. Through continuous small-scale production the B. F. Goodrich Company hopes to solve the more outstanding problems before the need for large-scale production may arise.

The oil-resistant type of Hycar is being used extensively in such mechanical goods as hose, gaskets and articles for the printing and automotive industries. The service given by the finished articles has proved to be very satisfactory.

The Hydrocarbon Chemical and Rubber Company has been formed by the B.

F. Goodrich Company and the Phillips Petroleum Company to integrate the production and sale of the crude synthetic rubber which is being offered on the market as Hycar.

Chemigum. The Goodyear Tire and Rubber Company has announced the small-scale production of "Chemigum" and is expanding its production. It is a butadiene copolymer of undisclosed composition which is resistant to oil.

The company is using "Chemigum" in regular production in various types of mechanical goods where oil resistance is important. It is proving satisfactory in such service. Experimental tires have been made and have given good service in tests.

SYNTHETIC RUBBBER IN THE UNITED STATES

As a national problem for the United States the synthetic rubber problem should be considered from two technical angles: (1) as a replacement for natural rubber, and (2) as an improvement over natural rubber; and from two economic angles: (1) under normal economic conditions, and (2) under emergency conditions. The views expressed here are the personal views of the author.

As improvements on natural rubber, Neoprene, Buna N, Hycar and Chemigum have already established positions in the American rubber industry because the superior properties which can be obtained with them are worth more than the added cost as compared with natural rubber. The production of Neoprene is now on a large scale (½ to 1 million pounds per month), although even this comprises less than one per cent. of the total rubber used. Substantial production of Buna N by the Standard Oil Company, of Hycar by Hydrocarbon Chemical and Rubber Company, and of Chemigum by the Goodyear Company is expected before the end of 1940. While in one sense these materials compete with natural rubber, they also tend to expand its use because they are often used with it in composite structures where rubber alone would be unsatisfactory.

The use of these materials is based chiefly on their resistance to oils, oxidation and sunlight. Butyl rubber is reported not to be resistant to oils but to have other properties which should lead to considerable use. With increasing knowledge other types of synthetic rubber may be expected with other special properties. There should be continued expansion of the use of these special synthetic rubbers regardless of the price of natural rubber.

Koroseal, Thiokol and Vistanex have also shown their worth under normal economic conditions. Thiokol is used principally for solvent resistant hose, packing, etc. Except for wire and cable covering, the uses of Koroseal and Vistanex are principally in fields where rubber has never been used to any great extent. Technically these materials might be substituted for rubber in a considerable volume of production, but ordinarily such a substitution would not be profitable.

The position of a synthetic replacement for natural rubber will depend on its relative cost and quality. Crude rubber is a high-quality product with excellent characteristics for factory processing. So far none of the synthetics has proved much better for any of the large volume uses. Hence, unless new advantages are discovered, the competition will be on a cost basis. This type of rubber will probably be either a polymer of a copolymer of butadiene. Its cost will depend considerably on the volume of production. For at least the next decade in this country petroleum appears to offer the most economical source of butadiene.

Rubber is one of the most important raw materials obtained almost exclusively outside of the United States, and

the continuation of an adequate supply is a vital part of any program of national defense. Even by the end of 1940 the total production of all the materials discussed here will probably not exceed 5 per cent. of the rubber requirements of the country. To satisfy this demand there will be required an industry with a capacity at least twenty times that of the present production of synthetic rubber, almost ten times that of the present dye industry and three to five times that of the present synthetic resin industry. Such production is not built up overnight, even under emergency conditions.

If shipments of rubber should be stopped, present supplies could be extended to meet requirements for about a year by expanding the production and use of reclaim and synthetics already in production. Plant construction and operation would be greatly aided by the knowledge already available from the production of various types of synthetic rubber. Even so, it would probably take two or three years to raise production to an adequate level. Such expansion is not normally practical and will require government support as a defense measure.

The National Defense Advisory Committee, in considering what might be done to replace rubber should its importation be prevented, is studying the problem of quantity production of synthetic rubber in this country. It seems advisable that definite plans should be made promptly so that the manufacture of synthetic rubber in substantial quantities can be started as soon as possible. Experience in its manufacture and utilization for the more essential rubber products will give assurance of the ability of the nation to replace natural rubber without delay should the necessity arise.

SCIENCE AND DEMOCRACY

ONE of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind; and that the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit. Mankind so far has been ruled by things and by words, not by thought, for till the last few moments of history, humanity has not been in possession of the conditions of secure and effective thinking. Without ignoring in the least the consolation that has come to men from their literary education, I would even go so far as to say that only the gradual replacing of a literary by a scientific education can assure to man the progressive amelioration of his lot.

Scientific method is not just a method which it has been found profitable to pursue in this or that abstruse subject for purely technical reasons. It represents the only method of thinking that has proved fruitful in any subject—that is what we mean when we call it scientific. It is not a peculiar development of thinking for highly specialized ends; it is thinking so far as thought has become conscious of its proper ends and of the equipment indispensable for success in their pursuit.

If ever we are to be governed by intelligence, not by things and by words, science must have something to say about what we do, and not merely about how we may do it most easily and economically. And if this consummation is achieved, the transformation must occur through education, by bringing home to man's habitual inclination and attitude the significance of genuine knowledge and the full import of the conditions requisite for its attainment.—*John Dewey, in "The Scientific Method and Study of Processes."*

HEREDITY AND THE PHYSICIAN

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THE belief by the physician that an intimate knowledge of the constitutional background of his patient is of distinct value to him has undergone changes in the past century. At a time when the "family physician" was indeed one who ministered to the whole family, who knew and treated the brothers and sisters of his patient, the uncles and aunts and the cousins, such a close understanding of the family fiber was to the physician a sixth sense. It supplemented what he heard, saw and felt in his patients, and taught him often to know what to expect and how they would react to his treatment. Thus he knew that Mrs. H. would probably be an invalid for weeks after her children were born, while Mrs. M. would be up and around within a week. He had learned that the N children ran a very high fever without much serious trouble, and that the T children were likely to have convulsions during relatively minor illnesses. When Mr. S. would come hurrying in to say that little Amelia, who was bright and well yesterday, was crying fitfully and running a fever, his first thought was, "Another running ear: whenever any of those children get a cold, they always have running ears." Or when Mrs. Z. came to him in her first pregnancy, he was more than watchful, for he had seen kidney complications in her grandmother, her mother and her older sister. He had seen little Tommy P. die of hemorrhage after he lost his first tooth, and he felt helpless when Tommy's little brother began to bleed from a scratch on the forehead, although he applied all the treatments recognized by the profession of his time. He knew that some of his patients would weather most illnesses and live to be old men and women, while others would fade quietly away from conditions not half so severe. Not always were his predictions correct, but the knowledge of the background of his patient helped him again and again, and his recognition of the constitution of the sufferer was often as important in his diagnosis, prognosis and treatment of the case as were the facts which he obtained through observation with his keen eyes, or through the tips of his sensitive fingers.

INFLUENCE OF BACTERIOLOGY UPON IMPORTANCE OF HEREDITY

And then a new order came to replace the old. Science taught that many of the diseases which he treated were due to infinitely small forms of life, entering the body of the patient perhaps through the nose or the lungs, where they grew into millions of other small forms of life, and thus caused the illness. The vogue of bacteriology with its precision in isolating the germ, and in finding that the same germ always caused the same disease, left well in the background the idea that the constitution of the patient was of great importance. If you developed tuberculosis when your mother had died of it, it was not because you had inherited the weak lungs of your maternal parent, but because you had been exposed to the tubercle bacillus that had killed her, and so you succumbed. Locomotor ataxia in father and son did not arise because they were related, but because both were exposed to the spirochaete of syphilis. Disease after disease was shown to be caused by bacteria, para-

sites, viruses, until it seemed that the constitutional background of the patient had little to do with his getting sick, and that the environment was responsible for all his ills.

As industry expanded, new chemicals brought new hazards; and more illnesses, formerly thought to run in families, were found to be dependent upon the similarity of occupation of various members of the family group. Also as industry grew and as transportation facilities increased, sons and daughters left the villages where they were born, and migrated to cities or to new lands. There they came into the hands of physicians who did not know them or their forebears; who treated them as individual patients and not as members of a family with certain traits. Migrations also made members of families lose contact with one another, so that a son in one part of the country or in a distant land did not know what his grandmother died of or what had been the character of the illness which took off his father in his early fifties. In this way, because the patient knew less of his family, he was able to give less and less information to the doctor; who in turn, because he got less and less information about the family from his patient, grew more and more cursory in the examination into the history of his patients' families, until finally we have the medical profession sinking to the level of writing on a history sheet, "Family history negative." As if the family history of a patient ever could be negative! None of his relatives may ever have had the same illness from which the patient suffered, but he had a father and mother; they were either alive or dead; if alive, they had reached a definite age and were either well or ill. If ill, they were ill of some disease; if dead, they died at a certain age and of some cause. The patient was either the only child in the family or there were others; if there were others, they were either younger or older, were male or female, were alive and well or ill; or had died of some cause at some age. There can be no such thing as a "negative family history," and the physician or the medical student or interne who writes that down acknowledges thereby that either he has been too lazy to inquire for the facts or too indifferent to write down the facts which he elicited.

True, it is not always necessary on a history sheet to write down a long discourse on the family of the patient. If a man comes in with a broken leg, acquired from having fallen from a truck, it probably does not contribute either to the diagnosis, the prognosis or the treatment to know of what his grandparents died or whether he has brothers and sisters. But if the patient states that his leg snapped when he was rising from his chair, a family history is of interest and importance. In other words, when the disease with which one deals is of *obvious* external origin, family history is not so essential, although it should be taken with care; but when the disease with which one is dealing is of constitutional origin, a family history may be of great significance and should be taken most carefully.

Discovery of the Laws of Heredity

Oddly enough not only did bacteriology and scattering of family groups play a part in lessening the emphasis on the value of heredity to the physician, but the discovery of Mendel's work and the keen awakening of the scientific world to the laws of inheritance discouraged acceptance of evidences of heredity in man. The use of forms like Drosophila in which a whole lifetime is telescoped into a few days, in which innumerable generations can be bred in the working lifetime of a scientist; or the use even of mammals like mice which may produce four generations to a year, instead of four to a century, so impressed every one

with the value of the experimental method in genetics that those unable to use such a method on human material, and able to observe at the most only three generations, perhaps not more than two, came to believe that what little they could observe in man was worthless. This attitude was to a large extent fostered by some geneticists who felt that unless the matings could be experimentally controlled observations were useless. Of course such an attitude was wrong. The observer of human material is handicapped to a tremendous degree, because he can not make experimental matings, nor do his subjects reproduce in large enough numbers for the data to be significant, nor can he examine the germ cells for cytological evidence of disturbances in the chromosomes. But all this does not preclude his making careful observations of matings that do occur, and of applying other methods than those of the experimentalist to his observations. Even the experimental geneticist often can not tell the hybrid form from the homozygous dominant until he breeds it to the homozygous recessive and finds that he has offspring of two kinds. If he mates two hybrids, he often can not tell which of the animals exhibiting the dominant trait is homozygous for it and which is hybrid. He must breed them to find out; and so it is with man. Observations on the results of human matings may be of as much value in some instances as are those on the progeny of controlled experimental matings; the difficulty is that they are so few in number and one has to wait for such matings to occur spontaneously.

The explanations which the observer of human heredity makes of his observations must of course rest upon facts which the experimentalist elicits from his controlled matings. He can test his data by the experimentalists' criteria, and arrive at conclusions that are worth while. After all, it is not of much value to the physician to find that a certain malformation is due to a deletion instead of a translocation of a specific chromosome in his patient. What is of infinitely more value to him is that if his patient has produced a child with a certain type of malformation, she may produce another such child, and that the chances of duplication of the deformity in later offspring are fairly large for some deformities and negligible for others. Even when he knows that the chances are one in two that a son of a carrier mother will develop hemophilia, he can not predict that the next child will be a son or, if it is, that it will inevitably inherit the gene for hemophilia. Nor can the scientist with his controlled matings under similar circumstances predict what percentage of the next litter of mice or of the next batch of flies will show a certain trait. Both can predict averages on the basis of laws of probabilities, but neither can predict accurately the specific traits which each offspring will show when his parents are not homozygous.

Reawakening of Interest in Medical Genetics

The pendulum is now beginning to swing back again to a belief that inheritance plays a large role in disease, and that the physician who knows the fundamentals of the laws of heredity and who knows the family background of his patient is better equipped to diagnose, treat and give a prognosis intelligently than is the man who lacks such knowledge. It is being recognized that, although bacteria cause disease, susceptibility and immunity to these bacteria are hereditary. Webster has shown with his mice that epidemics introduced at will into his colonies rage with violence or die out, depending upon the relative proportions of hereditarily highly susceptible or highly immune animals which he has placed in the population.

It has been shown that although the

physician lacks the experimental method in studies in human heredity, observations on many cases by many workers do lead to certain general principles which he can use, both in advising his patients and in diagnosing and treating their ills. There have been several factors responsible for this rebirth of appreciation of the importance of a knowledge of heredity to the physician. One is the fact that many more of the general public are being educated in colleges and are being exposed to the teachings of biologists. Here they may learn something of the general laws of heredity, and may learn to appreciate that man is subject to them as well as are the animals and plants whose hereditary traits they see exemplified in the laboratory. Medical students also are learning a little genetics in their premedical courses. A second factor is the popularization of science by certain writers, who put into the hands of the non-medical public simplified genetic truths as discovered in the laboratory. A third factor is the leavening influence of a few ardent students of human heredity, both within and without the medical profession, who strive to have genetic truths taught to the medical students who are to be the physicians of to-morrow. They meet with the objections that there is no time in the medical curriculum for any new subjects and that "there should be a closed season for medical students," that the students can pick these things up for themselves in the clinics, etc.

As Lord Horder once remarked, there would be room in the medical curriculum, were other *less important* things discarded, to make a place for a course in inheritance in disease. The students might be spared learning the times of appearance of all the ossification centers in the bones of the body, that being better typed upon a card and hung above the desk than carried in the head to the exclusion of more important matters. The same might be said of so much anatomical detail which the student is expected to cram into his mind, and which he never uses unless he does so at the autopsy table, at which time he can look up the standard measurements and weights of organs. He might give up learning what veratrin and curare do to frog's muscles, which he will never use in his clinical work, for the sake of learning the syndromes which he will meet in his patients. He will probably never hear of many of the hereditary disorders unless he learns of them in a course in genetics. There is not much use in hoping that students will read about inheritance in disease after they leave medical school unless they are taught the rudiments of the subject in their student days. To the physician who knows something of the laws of inheritance, and what types of disease are likely to be inherited, examples of hereditary disorders are constantly manifesting themselves; to the physician who knows nothing of this fascinating subject, they are completely lost.

The following is an example. Not long ago a friend told me of an acquaintance who had suddenly developed intense swelling of the eyelids, so that she could not see. Several physicians had seen her, treated her ineffectively, and she still remained a blind prisoner in her room. I asked if she had any relatives who had had similar experiences, thinking that she was probably a sufferer from hereditary angioneurotic edema. The victim was quite surprised when questioned whether any of her family had a similar trouble and asked how I knew. In view of the fact that this disease can be so swiftly fatal if it attacks the vocal cords, or the laryngeal mucosa, it would have been desirable for the physicians in question to have attempted first to detect any external factor which might bring on the edema, and second, if there was any therapy which would

reduce the edema, to give her directions to always have it about her, and to take it at the slightest sign of the trouble. None of the physicians had recognized the true character of the edema, nor that it could affect the laryngeal mucosa as well as the eyelids.

Value to the Physician

I have said that gradually more of the medical profession are becoming aware of the value of a knowledge of inheritance as a part of their professional equipment. How valuable can it be, and is it worth while spending time on teaching medical genetics in medical schools? First, it gives the physician an acquaintance with the laws of heredity that makes him a much more intelligent reader and writer of medical reports. It saves him from making the fallacious statements on heredity which now are a commonplace in medical literature. For example, we see the statement made repeatedly in medical texts, "Disease X is hereditary in a small per cent. of the cases, familial in a much larger per cent., and sporadic in almost half the instances." The percentages differ of course for different diseases. Or we may see that "Disease Y is not hereditary, it is merely familial." Such statements would not occur, of course, if medical students were trained in genetics and knew that sometimes a disease may run directly through two or more generations (the so-called hereditary cases) or it may be transmitted as a recessive and appear in several siblings without there being any history of it in ancestors (the so-called familial cases): and finally that it may appear in only one child in a family without there being necessity of denying its hereditary nature. If the disease is transmitted as a recessive, then the majority of cases will be "sporadic," since more families are likely to have but one affected than they are to have two or more affected. This is true in all families with five or fewer children. Not until we get to families with six or more children are we likely to find the majority of families with at least two affected with a recessive trait. But as families of six or more children form less than one fourth of the population, it is quite clear that the type of case designated as "sporadic" is the predominant type. It may nevertheless be dependent upon factors resident in the germ cell, and therefore hereditary.

If the physician knew some of the fundamental genetic laws, he would not make statements such as this: "Disease X is known to be a familial disease, but the patient here described is the only one in the family affected. Therefore this child can not have disease X, although all the symptoms and findings are suggestive of that diagnosis." It would seem obvious that some child in the family has to be the first to be affected; it would be most unusual to have all the potential victims develop it simultaneously. As just stated, if the disease is transmitted according to the recessive, one child only in the family will be affected more often than will two or more.

Xeroderma pigmentosum, a cancerous degeneration of the skin, is admittedly dependent upon a recessive gene substitution, and hence hereditary; nevertheless this disease affects only one child in the family in about two-thirds of the families, and more than one child in the remaining third.

The genetically trained physician would not decide that amaurotic family idiocy was not dependent upon recessive genes in the family he described because it failed to show the 3:1 ratio expected in such cases. He might find only one out of twelve children showing the anomaly; but he would know that of all families of twelve children in which amaurotic idiocy occurs, one in every seven families will have but one of the children affected, the other eleven chil-

dren being normal. He will understand that although one fourth of a family where both parents are normal but carriers of a recessive trait will be affected on the average, not all families in actual life will have the ideal percentage of 25 showing the disease. He will not even demand that a *series* of families in which amaurotic idiocy is found should have 25 per cent. affected; he will know that if he has a series of families he will probably find considerably more than 25 per cent. with this anomaly. He will not say that polydactyly is not behaving as a dominant trait in the family he reports, merely because 4 of 6 children, instead of an expected 3, have too many fingers. These things he will know and he will be saved from making gross errors which serve to lessen his scientific reputation.

But the average physician may object that he has no intention of writing articles for journals, and if he did he would not attempt to discuss the hereditary angle of any disease. Are there, therefore, any more tangible benefits to be derived from a study of medical genetics than that of making him a more educated man, or than the mere saving of face?

Medical Genetics Helps in Diagnosis

It is quite obvious that the most important, as well as the most difficult, part of medical practice is to diagnose correctly. If one has the diagnosis, then even the less intelligent can look up in recent books on therapeutics the most approved treatment, and carry it through with a large share of success. The crucial thing is to diagnose properly. Now a knowledge of medical genetics will not enable one to diagnose all disease by any means, but it will help not infrequently if one's mind is alert to its possibilities. Let me give a few examples. These could be multiplied many times, and they have not been chosen because they are the most spectacular, but merely because they are actual instances in which a knowledge of inherited disease has helped the physician, and are instances which are known to me.

A child of ten or thereabouts developed a large bony growth on his arm. The pediatrician, suspecting a malignant growth, had an x-ray picture taken of the arm. The roentgenologist pronounced it sarcoma and advised immediate amputation at the shoulder. The parents were unwilling to have this done, but when the swelling increased in size they demanded the opinion of other physicians. The child was taken to another city, and there the surgeon who was consulted diagnosed a bony exostosis. He not only showed that there were other beginning bony excrescences on the child's skeletal system, but also that the father who had accompanied the child had bony exostoses, none of which had ever grown large enough to call his attention to them.

A man was brought to a physician with a history of repeated hemorrhages from the stomach, the last so severe as practically to exsanguinate him. The diagnosis rested between several possibilities, one being gastric ulcer. Should diet or surgery be employed? The father of the patient volunteered the information that he had suffered from profuse nosebleeds all his life. To the man unacquainted with hereditary diseases (and again let me emphasize that many of the hereditary diseases are not mentioned in the ordinary course in medicine, and hence the student is unaware of their existence), there would seem to be no connection between epistaxis in the father and gastric hemorrhage in the son. But to the genetically initiated, the possibility that the father had telangiectasis in the blood vessels of the nasal mucosa, while the son had the same anomaly in the vessels of the gastric mucosa, was very real. Exploratory operation, with the wall of the stomach il-

luminated, showed that the physician's "hunch" was correct and a large dilated thin-walled vessel which had ruptured was found and excised. The patient recovered and his gastric hemorrhages stopped.

A child of about eight, with thin, sparse hair, dry skin and a few irregular teeth, was taken to a physician for treatment. The diagnosis of myxedema was made and the child was given thyroid medication. He did not improve, but seemed definitely worse and finally refused to take any more medicine. He was then taken to another physician who had heard of hereditary ectodermal dystrophy, and who recognized that the thin, fine hair, the absent teeth, the dry skin might all be explained by the fact that in the development of this child, something had gone wrong with the derivatives of the ectoderm, so that he lacked most of his hair follicles, most of his tooth buds, and all or most of his sweat glands. Examination of others in the family showed that the mother, too, had fine sparse hair, dry skin and lacked some teeth. It was true that the correct diagnosis could not initiate an active correct treatment, but it could bring about one that was passive, which was to leave the child alone. He was already suffering from inability to regulate his body temperature through evaporation of sweat, and suffered intensely in hot weather because of that failure in his heat-regulating mechanism. The first type of treatment whipped up his metabolism to a higher rate and made him even more uncomfortable than before.

Recognition of this syndrome of ectodermal dystrophy in children may be of great therapeutic assistance when they develop childhood diseases, for they run a grave risk of dying from lethal temperatures following mild infections, because of inability to lower the temperature by evaporation and radiation. Treatment directed toward keeping the temperature within bounds may save them.

The Value of Medical Genetics in Treatment

Naturally, if diagnostic ability is improved, therapeutic measures will improve accordingly. If the bony lump is diagnosed as sarcoma, amputation is the treatment prescribed, but if an exostosis is recognized, the arm is saved. If gastric ulcer is suspected a dietary régime may be instituted, which would help the ulcer, but leave untouched the dilated blood vessel causing the trouble. If what looks like a fractured clavicle does not heal, the patient may be subjected to several operative procedures to insure union of the ends of the bone; but if the physician has recognized that the clavicle on the other side which was not broken also has ends which are not united, he recognizes his patient as an example of cranio-cleido-dysostosis and does nothing. No completely rational treatment can ever be given until the physician knows what is wrong with the patient. I recall two small boys, both of whom were diagnosed as problem children by psychologically minded physicians. The first, although six, suffered from enuresis. Despite punishment, various kinds of treatment, etc., the child continued to wet his bed. Finally he was taken to another physician, who looked at him not as a psychological but as a physical problem, and elicited from the mother the fact that the child drank huge quantities of water at all times, even during the night. Realizing that he wet the bed because he drank so much water and that he had diabetes insipidus, he diagnosed the case as the Hand-Schiller-Christian syndrome, in which xanthomatosis of the bones of the skull, exophthalmos and diabetes insipidus are present. That physician controlled the enuresis by proper medication. Up to the present, this disease has not been

included in the category of hereditary diseases, but it probably will be found to belong there. It is due to an anomaly of lipoid metabolism and as such very probably has a genetic basis.

The other little boy was considered a problem child at a very early age by an over psychologically minded pediatrician. He vomited practically everything which was given him except his mother's milk. He was looked upon as having such a strong maternal fixation that he would eat no food other than hers without vomiting it. But his father was an asthmatic, a sufferer from hay fever and strongly allergic to a number of foreign proteins; his mother was highly allergic to several plants, and her whole family for three generations were allergic to various foods, plants, dyes, etc. When he was finally recognized as a product not of psychological traumata, but of his hereditary allergies and when rational treatment of gradual immunization to egg white, to cow's milk, etc., was instituted, he ceased being a problem child.

If the physician has heard of the hereditary disorder known as periodic paralysis he may bring his patient out of an attack or may inhibit an attack by injection of potassium salts. But if the practitioner has never heard of this syndrome, he may be non-plussed or think that the patient is malingering; or he may even try to psychoanalyze him out of some subconscious complex.

The condition known as myotonia congenita or Thomsen's disease has a curious history. The man who first described it was himself its victim. It consists of difficulty in initiating or stopping voluntary motion. Thus the man who wants to shake hands with you can not raise his hand quickly enough to meet yours, but when he finally clasps your hand firmly, he continues to hold it in an ever-increasing embarrassment. The son of the doctor who first described this syndrome was being punished for malingering by the military authorities, for he could not (or would not, as the officers thought) obey an order promptly. He could not march when the order was given; then when his comrades were ten paces away, he would start up slowly at first but with ever increasing acceleration until he was marching normally. But when the order to halt came, he still went on walking for about ten paces more. The father, who had managed to keep his defect to himself, by never making any sudden move and by concentrating for some moments before he made any motion, revealed his condition in order to save the lad from punishment.

Although this condition was described many years ago, it had been forgotten, and when two brothers, both with the disease, were drafted in the German army during the War of 1914, they underwent for months much the same experiences as those just related. Finally the medical officer before whom one brother came for examination after having served kitchen duty for his supposed disobedience, recognized the disease, and the soldier was dismissed. He then managed to get his other brother out of the army also.

A patient whose brother had developed gastric carcinoma had his symptoms of digestive disturbance treated by a genetically minded practitioner with far more concern than would have been the case had there been no such family history. Twins developed breast cancer, several years apart. Later another primary cancer in the other breast developed in each twin; and finally an ovarian carcinoma occurred in the first twin. Should the ovaries of the second twin be removed as a preventive measure or should she merely be watched? If the latter course is adopted, it is safe to say that if she develops ovarian carcinoma, it will be detected at an earlier date than it would have been had there been no hereditary history of it.

Medical Genetics in the Field of Preventive Medicine

If it is easier to diagnose disease, it becomes as a matter of course easier to treat it and ultimately to prevent it.

Our eyes have been turned so constantly on the infectious diseases that we have largely forgotten that preventive medicine in the realm of inherited disease also furnishes a very large scope for our ingenuity. And so successful have we been in the realm of infectious diseases that many which formerly claimed a large percentage of the population have been completely or almost completely eliminated. With each advance in that field we will be confronted in ever greater numbers by hereditary diseases, and if we would avail ourselves of all opportunities for preventive work we must begin to bring these diseases into the orbit of our consciousness. Some hereditary diseases will be impossible of prevention, since we can not know what initiates them other than that they are dependent upon hereditary factors, but in some instances we may prevent their manifestations. Thus in periodic paralysis, we can not prevent the sufferer from inheriting a peculiar potassium metabolism, but we can prevent the symptoms from appearing by furnishing him with potassium. In pernicious anemia, we can diagnose the early stages of the disease in those who have not yet developed it, by looking for the gastric juice alterations that seem to be its forerunners. Long before the blood picture in the circulation alters, or before the hemopoietic system undergoes its primary change, and long, long before the nervous symptoms are manifested, one can detect the achylia gastrica in potential pernicious anemia patients. By proper therapy it may be possible to prevent the actual disease symptoms from appearing. Whether this will be completely and always possible we have yet to see; this form of preventive medicine is too young for us to make any pronouncement upon it.

Cardiovascular disease has long been first in the list of "causes of death." Many of these conditions are of course not hereditary; they are due to damage done to heart and vessels by some infectious condition. These are being lessened materially, and hence the cases of cardiovascular diseases that are left will become increasingly more and more of the type that depend upon hereditary factors. Hypertension, at least some forms of it, runs in families, and hypertension is one of the elements in the cardiovascular death rate. If we can find some therapy that will prevent the pressure from rising (and recent work shows promise), and if we are able to detect the members of the family who are potential hypertensives, then we may administer the medication, thus preventing or inhibiting the appearance for a long time of the heightened blood pressure.

The earliest onset of diabetes may be detected if the physician is watching for it in members of a family in which it occurs. By proper dietary régime and administration of insulin, the full effects of the disease may be prevented. Cancer of the rectum may be forestalled by removal of the polypoid growths in persons as yet unaffected with cancer. Cancer of the uterus may be prevented in some women whose female relatives are prone to develop cancer of the uterus by having the uterus removed after the number of children desired has been born. Numerous examples of the preventive side of hereditary diseases will occur to the alert practitioner.

Advice to Parents

One of the direct means of preventing hereditary disease is, of course, not to have the potential victims of the disease procreated. If a woman has given birth to one boy with hemophilia, the voluntary restriction of her family will pre-

vent subsequent sons in which the disease might develop. Since she will have no more daughters who may have sons to bleed, she prevents the disease from being passed on to future generations. A woman who has had one child die or lose his sight from retinoblastoma can limit her family, thereby preventing other potential victims from being born. If the hereditary disease is one which appears early in the life of the individual, then family limitation can be of value in wiping out the disease; but if it is one that appears when the child is fully grown, then the mother has probably had all her children before she knew of the defect in her offspring.

If the disease is one that is deleterious and is transmitted as a dominant, then the affected persons can refrain from procreation if the defect appears early enough in their lifetime; or if it be one which occurs after the persons have had their offspring, but is undesirable, then *potential* victims of it should not have children. Thus a man or woman, one of whose parents has developed Huntington's Chorea, stands an even chance of inheriting the disease. It may not show up in them until 45, but it so completely wrecks the life of the patient that such persons should not reproduce even if they are not sure that they have inherited the malady. Just one generation of refusal to bear children on the part of those whose parents have developed this disease would mean its elimination.

We must use our common sense in giving advice in this field of preventive medicine. If the defect or disease is one which has not been appearing until the patient has lived a long useful life, not only is it useless to try to prevent the disease from being passed on, but it is undesirable to do so. Take cancer, for example. If a man dies of rectal cancer at 70, one can not breed out that disease from his family, for all his children and probably all his grandchildren will have been born before his disease overtakes him. The only way to wipe out cancer from that family would be for all his descendants who were still young enough to procreate to refrain from reproducing. It would be far better to have them and their descendants as good citizens for 60 or 70 years, dying of cancer in old age, than to have their stock lost to the community in order to wipe out that strain of cancer. Moreover, it is not at all certain that they have inherited the factors for rectal cancer; or, if they have inherited them, it is not at all certain that they will live long enough to die of their inherited condition, because death at an earlier age from some other disease is likely to occur. If, on the other hand, it is a tumor such as retinoblastoma which is taking the child at an early age, and which either means death or disfigurement, those who are likely to have offspring with such a tragic inheritance should refrain from reproducing children whose heritage is far from being a goodly one.

If one's mental and physical endowment is good through a long lifetime, and if the hereditary disease is not one which means leaving the patient for years to be cared for by the community, it would seem unwise to attempt to breed out the hereditary disease. If it is one that is devastating in its effect, and appears at an early age, parents have no moral right to bring children into the world who may suffer from such diseases, if they know that such probabilities exist. The final balance must be struck after weighing the time of onset and balancing the good qualities that the patient may inherit against the undesirable ones which are also to be his portion. Unless the onset is late and the good far outweighs the bad, then it were better to

> Cancel from the scroll,
> Of Universe, one luckless human soul,
> Than drop by drop enlarge the flood
> which rolls,
> Hoarser with anguish as the ages roll.

A knowledge of inheritance is of value when the physician is asked to give advice to a mother who has had a malformed child. She wants to know whether she is likely to have another such mishap. No matter how rare the defect, the physician can not assure the parents that such a mistake can not occur again and that subsequent children are certain to be normal. If such assurances are given, the unexpected often happens and the mother has a second defective child. It is heartbreaking for the parents who have relied upon the doctor's assurances when such an accident occurs and it is detrimental to the doctor's prestige, and not infrequently loses for him the family and their friends as patients. Following are a few examples known personally to have occurred. A mother who was an elderly woman at the birth of her first child had the tragic experience of having it bleed to death from hemorrhage of the lungs at one day. This occurred before the days of Vitamin K. Feeling that she had perhaps not had the best prenatal care in the village where she lived, she went to a city during her next pregnancy and placed herself under the care of a specialist for several months before the second child was born. The same thing happened, and her child bled to death before it was one day old. But she had undergone that second pregnancy after she had been told that "It could not happen again." Another mother whose first baby had a trident hand was informed that nature might play that trick once but not twice in a family. Her second baby was a duplicate of the first, and the family changed doctors.

With some defects, one can almost, but not quite, guarantee that the mother will not have other children similarly deformed, while with other defects it is almost certain that she will have other children similarly affected. Thus a mother who has had one anencephalic baby is likely to have a second malformed child who probably will also be anencephalic. A mother who has had a baby born with an arm missing can not be assured that her subsequent children will be all right, but the chances are much in favor that they will be normal, especially if the parents were not related.

The Physician as a Record Gatherer

Not only should the physician be trained in genetics for the added breadth of knowledge it affords him, for the greater benefit which it brings in diagnosis, treatment and prevention of disease, but he should know what is of value for genetic records. The geneticist is not in a position to gather the data from which the general principles of human genetics are drawn; the physician is the only one who can do that. But he is not trained and hence much of his record taking is useless for the medical geneticist who would use his data together with those of other physicians for formulating laws. Thus in reporting a case of inherited disease, he may inquire as to whether the parents were related, but if they say no, he does not record that fact. The geneticist does not know if this point of consanguinity was inquired into, and the answer found to be negative, or if the physician never thought to ask about it, in which case the parents might have been related. Again the child with the disease may be the only one affected in the family. If the record states that there were four other normal children, the record is of value, since it serves for pedigree analysis; but if the record does not state whether there were other sibs or if so, how many, such a record is worthless. If repeatedly large families of ten or twelve children are found with but one child affected, then one is constrained to find some other interpretation than that the disease is dependent upon a recessive gene substitution. A few such families are expected, but they should not be in the majority. Hence

the number of sibs is important, and the genetically trained physician is so aware of this that he would not omit such information from his record.

The age of onset is important. If the disease begins at 15, and the patient is the oldest in the family, the fact that the younger sibs under 15 are unaffected does not mean that they are necessarily normal. They may develop the disease later on. But if all were older than the patient, it might be assumed that they were really normal. The genetically trained man will realize the importance of such information and record it.

He will not speak of the patient as "it" or "the child" or "the patient" but will give the sex, for some diseases are more prone to occur in one sex than the other, and the mode of their inheritance may be determined by the sex distribution. Therefore the sex will be recorded. All the other data will be recorded briefly and in usable form.

The Importance of Records on Twins

The genetically trained physician will appreciate the importance of twins in the field of genetic research and will not only keep records on all pairs of twins among his patients, but will record them in the literature in usable form. He will not select cases in which both twins were affected with a similar condition, but will report as well *all* cases in which one twin only was affected. He will know that any conclusions he reaches on identical twins must be controlled by similar observations on fraternal twins. Records will not appear in which the following are not clearly stated: (1) the sex of both twins, (2) whether they resemble each other very closely, or are unlike, and if possible (3) what their blood groups, their coloring, their physical measurements are, and (4) pictures of well-taken finger prints, so that the reader can estimate the validity of the criteria upon which their mono- or di-zygosity was judged. More careful examination of the membranes will be made before it is stated that the twins were monochorial, and hence from one egg, especially if the two show widely dissimilar characters. The possibility that the twins are from two eggs, that the placentae have fused, and that the membranes also have closely fused, giving the appearance of but one chorion, when there are in reality two, will be considered, and the true state of affairs recorded. Perhaps no one man will see enough twin pairs with any specific inherited trait to make his own records worth analyzing, but if his records are published, they will be a veritable treasure house for the trained medical geneticist.

The physician who is the guardian of his patient's health, who is the adviser and friend of his patient, will find his ability to diagnose and treat that patient's ills enhanced, and his counsel better founded if he is genetically trained. Moreover, he may become a true research worker, not in the laboratory with chemicals or animals, but in the realm of human genetics, by painstakingly recording the accurate details of his patient's background as well as of his hereditary illness, and by making these available to the geneticist who can analyze them accurately. Many physicians regret their inability to do research through lack of time, lack of money, lack of facilities for undertaking the study of some problem. The field of human heredity offers them their greatest opportunity; for there is scarcely a physician who does not encounter some case that offers chance to contribute valuable data toward the solution of some genetic problem.

AMATEUR SCIENTISTS AND THEIR ORGANIZATIONS

By W. STEPHEN THOMAS

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TO-DAY, "amateur" and "professional" are terms used with increasing emphasis in reference to many spheres of human endeavor. From athletics and politics to literature and gardening we make a distinction between the person who carries on a certain activity for his livelihood and another who engages in it for quite different reasons. Science is another domain in which sharp differences are drawn between amateur and professional participants. Although we can not forget that amateur can be used in the sense of dilettante or trifler, when we speak of an amateur scientist we mean one whose interest in science takes the form of a leisure-time hobby or avocation in contrast to the professional who has formal training and makes his living in his chosen field. In this latter use, the word "amateur" conveys the same meaning as when employed in a sporting sense, a connotation which is, indeed, a favorable one.

Not more than a generation or two ago scientific research had not yet been dignified as a profession. Priests, teachers, doctors, artists and laymen of many sorts carried on important investigations and made outstanding contributions to the sum of knowledge. Leeuwenhoek, Herschel, Darwin and Mendel are a few of the brilliant figures who did not make their living from science. To-day, thousands of persons throughout the United States, especially those in urban and suburban communities, are following scientific pursuits as a form of recreation. These do not include that equally large body who make their daily bread from science in one way or another. Most of these avocational scientists or amateurs are educating themselves in many branches of scientific knowledge; a major portion of them are learning scientific techniques. A great many are recording facts and compiling data which will be useful to professional scientists. A few are making original contributions to knowledge.

Concrete examples of amateur aid to science come readily to mind. Among these, the work of the amateur astronomers has deservedly attracted attention, while the collective efforts of the Society of Variable Star Observers, a selected group of these amateurs, has a high ranking in original investigation. We may mention, also, the amateur botanists, entomologists, geologists, mineralogists and zoologists, who, here and there, have advanced knowledge throughout the land by making collections and recording data on the distribution, ecology and life-histories of plants and animals. Although the volunteer observers, stationed throughout the country assisting the United States Weather Bureau in keeping records, are essentially compilers, they are amateur scientists. In a similar category are the bird students whose check-lists of species are invaluable records and whose work in banding aids specialists in probing the mysteries of migration. In far smaller numbers occur the amateur chemists and physicists, but these devotees are none the less represented. On the other hand, in the many branches of the applied and social sciences such divisions as agriculture,

horticulture, archeology, aviation, economics, history, mechanics, photography and radio can claim hosts of leisure-time enthusiasts. In numerous cases the skills and abilities of these amateurs are pronounced, so much so that important contributions have resulted from their efforts. To specify but two examples, one can point to the rapid developments in color photography and radio which are achievements for which amateur experimenters are given much credit. Very appropriately, Dr. Edwin G. Conklin has said, "Some of the best work ever done in science has been by amateurs and the spirit which has led them on has been the spirit of adventure and discovery. . . . It is essential for the normal development of human beings that this spirit should be cultivated and it is highly important for the development of science itself."[1]

Apart from the contribution of amateurs to the advancement of science lie other reasons why professionals, as well as the public at large, should ponder upon the significant role which may be played by these laymen. Science, to-day, has many more social implications than it had in the past. People whose everyday lives are materially improved by the discoveries and applications of science often feel they have a duty to acquire a general understanding of it. Furthermore, the future of research is a matter closely concerned with the attitude toward science held by the man in the street. It is quite likely that, in the future, financial aid for original investigation will come less from private and semi-private sources in the form of endowments for scientific and academic institutions and more from the public in the form of taxes. On this account, if for no other reason, the general public will need to know more about science and the scientific method.[2] Laymen of all types, who have gained practical experience in some scientific specialty such as the collection and classification of insects, or, let us say, the construction and use of a telescope, would certainly tend to have a more intelligent comprehension of science, both in fact and in method, than individuals limited to sporadic reading or forgotten school and college courses. At the same time, the person with a scientific hobby can be an interpreter of technical subjects to his neighbor. He can serve as a liaison between the research scientist and the common man in diffusing the spirit of science. It is this spirit of the scientific method that, above all things, must be imparted. It shows itself in the estimating of evidence, in the training in facts rather than fancies and in the use of the trial-and-error method of thinking. For every one to-day, nothing is more needed.

To popularize science in the best sense is a difficult task. Lately, considerable thought has been directed to this problem. A survey made in 1934 by Dr. Benjamin C. Gruenberg revealed the startling fact that of all the offerings in adult education only from five to six per cent. were in fields of science.[3] Here was one factor to account for public ignorance, namely, the lack of opportunity for learning about science. The situation evoked the question as to what suitable means might be used to bridge the gap between science and the public. Were formal educational methods, such as books and courses the only way, or might there, perhaps, be other avenues of approach?

In order to make a specific experiment testing the possibilities of amateur education in science in a limited area, Dr.

[1] E. G. Conklin, "Activities in Science in the Philadelphia Area." A circular of information. American Philosophical Society. October, 1939. No. 1.

[2] Morse A. Cartwright, *Jour. of Adult Education* 11: 3, June, 1939. p. 356.

[3] Benjamin C. Gruenberg, "Science and the Public Mind," p. 141. McGraw-Hill, N. Y., 1935.

Frederick P. Keppel, president of the Carnegie Corporation of New York, requested the American Philosophical Society to undertake a survey and program of action through a special committee of its members.[4] This Committee on Education and Participation in Science, composed, for the most part, of research scientists distinguished in their fields, were members of the society and outlined the policy of the program. The group consisted of the following: Dr. Edwin G. Conklin, *chairman*, Drs. Anton J. Carlson, Karl K. Darrow, Luther P. Eisenhart, C. E. Kenneth Mees, Oscar Riddle, Harlow Shapley, George G. Simpson, W. F. G. Swann, Edward L. Thorndike, Harold C. Urey and Roland S. Morris, *ex-officio*. The project, inaugurated in June, 1939, was not only directed toward amateur scientists but emphasized the actual participation of these persons in scientific activities. An area within 30 miles of Philadelphia was chosen for study. The result of the findings of this Committee on Education and Participation in Science, operating with an executive staff of scientific consultants, was to inaugurate a series of volunteer programs to test the effectiveness of amateur efforts, both as self-education and as an aid to science. However, the aim of this article is to reveal and interpret some of the data concerning the whole subject of the amateur and amateur science. First, the characteristics and interests of the former will be discussed; and, second, there will be examined the organizations which have been formed to accomplish the multiple aims of recreation, self-education and original research. Although the data used were obtained in the Philadelphia area, it is believed that the facts will serve to represent other regions as well.

[4] Frederick P. Keppel, "Responsibility of Endowments in the Promotion of Knowledge," American Philosophical Society, *Proceedings*, Vol. 77, No. 4.

The Amateur Scientist

There are not a few reasons why the general public should be rather vitally concerned with increasing its understanding of natural phenomena as well as acquainting itself with the various sciences applying to our universe. The rising educational level, manifested in part by the growing number of high-school and college graduates throughout the country, together with a greater diffusion of general information through print, motion pictures and the radio, are influences leading to a greater alertness of our people. One specific indication of this fact is the growing desire of some individuals to learn more about their environment and to enjoy it intelligently. City populations, thanks to the bicycle and automobile, are not restricted to their urban background. They can move cheaply and quickly to the out-of-doors. Combined with shorter working days and longer vacations, these factors increase the range for action in one's leisure-time. We see evidences of these influences in the hiking and camping fervor which sends annually into the mountains and woodlands hundreds and thousands of young and old persons and, again, in the broadening influence of gardening on great numbers of dwellers in the suburbs and in the growing desire to know more about and to protect wild life. All these tendencies relate closely to an inquiring attitude toward the sciences upon which forestry, biology, horticulture and conservation are based. Immediately connected with the applied sciences are the daily interests of persons in the machinery and gadgets which are interwoven with our modern living. The mechanical precision and technical proficiency of the automobile and airplane engine, the radio set and the camera have captured the imaginations of hosts of laymen who wish to know more about mechanisms and their functions.

Such curiosity often leads to the sciences lying behind these inventions.

Who, then, is the genuine amateur scientist? For our purposes, he, or she, is the one seriously enough interested to participate in some activity in science as a leisure-time pursuit. First of all, he follows his hobby for the sheer joy he derives from it, but that hobby, generally speaking, represents a sustained and, often, consuming interest. There is frequently an esthetic and intellectual appeal. Second, it is an interest which involves self-learning and self-improvement in most cases. In this respect it is more than a mere pastime. The means of learning about a subject and mastering it by the hobbyist may be conventional or they may be self-devised and ingenious. One interesting point to consider is that so many amateur pursuits in science involve the use of both hand and brain. Furthermore, almost all amateurs who have advanced in their fields of science have perfected some skill or technique. Finally, and third in the list of characteristics of scientific amateurs is the desire on the part of the more advanced of them to do original work or investigation which will add to the sum total of knowledge.

To supplement and clarify such statements as the foregoing it may be helpful to supply some detailed information. As part of the committee's preliminary study, a survey was made of a selected group of 300 adult men and women who had active interests in science. These persons were interviewed by the writer through the means of a questionnaire, filled out at twelve different meetings held by amateur clubs and societies, adult night schools, institutes and museums.[5] The individual tastes of these persons showed a wide diversity. The twenty-eight different fields of science which were indicated as holding interest are as follows:

anthropology	horticulture
archeology	mathematics
astronomy	medicine and public health
aviation	metallurgy
bio-chemistry	meteorology
botany	microscopy
chemistry	mineralogy
embryology	oceanography
entomology	ornithology
fish culture	photography
general natural history	physics
general science	psychology
geology	radio
geography	zoology

Now, it will be seen that these hobbyists are not only the amateur astronomers who grind lenses or are the banders of birds, but, also, the gardeners, radio operators, fish culturists and many others who, in the course of their recreation, follow bypaths inevitably leading to scientific inquiry. Many individual cases may be cited demonstrating how intelligent curiosity may bring about worthwhile results in the form of a permanent and active interest in a subject. There is the actual instance of the city-dwelling insurance salesman who, on a country walk, wondered about the inclination of bees for certain types of pollen. This curiosity induced him to become not only a skilled apiarist but a student of cross-fertilization in flowering plants. Other real cases are the railroad lampman who carries on experiments in physics and the real estate broker whose daily route through a mid-city park resulted in his becoming an authority on bird migration in his territory.

In making this analysis, there are some additional and pertinent facts revealed by the committee's study which are worth mentioning. One of these is the average age of the participants. Out of the 266 persons who reported their age, the mean was 36.5 years, and of the whole group of 300, 64 per cent.

[5] W. Stephen Thomas, Committee on Education and Participation in Science, American Philosophical Society, Progress Report No. 2, February 22, 1940, p. 6 (unpublished).

were men and 36 per cent. were women. The survey also revealed some interesting points concerning the amateur as a human being. That the average representative leads a well-balanced life seems to be indicated by the non-scientific interests listed. Recreations varying from golf and tennis to bridge playing and knitting were often mentioned.

As for the daily occupations of these people, 91 per cent. were employed and 9 per cent. were not regularly employed, but of these, at least half were either in the leisure class or had retired because of age. In the midst of the present situation of wide-spread unemployment in many fields, this last factor is an interesting commentary. In all, some 77 different occupations were represented by these science-minded laymen and laywomen. Twenty-one per cent. of the total, or 64 persons, followed some of the professions, being engaged in engineering, law, medicine, the ministry or teaching. Seventeen per cent. were occupied in business or office work of the white-collar type. Fifteen per cent. were skilled workers, including mechanics (3), printers (4), patternmakers (3), brick masons (2), a wood carver, a wool dresser, a plasterer, a carpenter, a postman, a police sergeant and a restaurant counterman, to mention a few of the various callings. Students made up 9 per cent. of the total number, but the majority of these seemed to have interests in science aside from their studies. And, finally, 6 per cent. were scientific workers or technologists, including one astronomer, nine chemists, a pharmacist, a photo-mechanic and a mineralogist.

Amateur Scientific Organizations in a Metropolitan Community

A desire to share one's interests with a group of congenial persons is often manifest among amateur scientists. This tendency is particularly shown by persons in the beginning stages of a hobby. Sometimes, if sufficiently advanced, the amateur later becomes a confirmed individualist and avoids a group. But, generally speaking, the club spirit prevails. It is, also, an incentive to productive amateur work. Dr. H. L. Hawkins writes of a similar situation in respect to amateur scientists in Great Britain:

> Sociability is, however, the key to the success and almost a *raison d'etre* of a local (amateur scientific) society. Unless this is an association of friends, it belies the name and loses its efficiency. It is not in the academic eminence of its members, but in the spirit of cooperation and enjoyment that the value of the society lies. . . .[6]

The selected amateurs, interviewed in connection with the Philadelphia survey, showed the important part which organizations play in stimulating and promoting interest. Forty-nine per cent. of the whole group questioned belonged to one or more amateur clubs, while 41 per cent. expressed a desire to join one or more additional organizations, despite the fact some of them were already members of groups. Several of these last-mentioned persons stated their wish to become members of clubs in fields in which no amateur organizations now exist in their locality. These fields were anthropology, chemistry, metallurgy, meteorology and psychology.

It was precisely because of the importance of the amateur scientific organization and its role in creating a wider understanding of science that the American Philosophical Society's committee, through its executive staff, made an intensive study of the groups in the Philadelphia region. They found here 287 clubs and societies, representing a total of 32,000 members, which, in the broadest sense, were concerned with the sciences. These organizations may be divided into two main groups. First,

[6] H. L. Hawkins, *Science*, 90: 2334, 262, September 22, 1939.

those with interests strictly in the pure sciences and these include the amateur astronomers, botanists, chemists, entomologists, microscopists, etc. There were approximately forty of these; and, second, a much larger division of more general scope. Under this category are placed the members of garden clubs, the aviation hobbyists, the amateur photographers with 85 separate clubs, the radio amateurs (1,700 licensed operators) and, lastly, a very large body of hunters and fishermen.[7]

While viewing the picture of amateur groups in and around Philadelphia, the third largest city in the United States, it seems worthwhile to touch, for a moment, on the significant background of this metropolis as a center for research and education in science. In colonial days medical teaching and practice gained an early foothold in the city. The University of Pennsylvania, the Library Company and the American Philosophical Society, all founded in the early eighteenth century, were other factors contributing toward making the city a focal center of learning. The last-named institution, with an intercolonial membership for promoting useful knowledge, was an especially potent force. In its early years it was virtually an amateur group and played a leading role in stimulating that spirit in the sciences. Residents of the city, frequently lawyers, ministers, merchants and often physicians, showed a bent for the physical and natural sciences as diversions. Prominent among them were figures like Benjamin Franklin, with his experiments in electricity; David Rittenhouse, clockmaker, and the Reverend John Ewing, a minister, both eminent contributors to astronomy; John Bartram and his son, William, among the earliest botanical students in America; and the physicians, John Morgan, Benjamin Rush and Casper Wistar, who had interests in a number of the sciences.

Another influence for such activity was the Quaker attitude. Members of the Society of Friends often showed strong leanings toward the sciences as recreational pursuits. With art, music and dancing frowned upon as worldly pastimes, activities of a scholarly type, such as archeology, bird study, botany and horticulture, were undoubtedly welcome as esthetic and intellectual outlets. Leading Quakers who distinguished themselves in these fields were the Bartrams, already mentioned, James Pemberton, merchant and philanthropist, who collected materials on the Indians, Thomas Say, the entomologist and zoologist, and William Darlington, the botanist, to mention but a few.[8]

In the first quarter of the nineteenth century a strong influence toward popular diffusion of science in the vicinity of Philadelphia gave rise to several academies and institutes which were established and supported chiefly by laymen. The oldest of these is the Academy of Natural Sciences of Philadelphia, founded in 1812 entirely as an amateur venture. It was started by two manufacturers, two physicians, a dentist, a chemist and an apothecary. For most of the years of its existence the academy has had affiliated with it America's leaders in descriptive biology and the earth sciences. The academy to-day is important as the meeting place of ten active amateur scientific societies, representing a membership of over 1,800 persons. Nearby is the Franklin Institute, founded in 1824 for the study and promotion of the mechanic arts and applied sciences. At the present, its large modern museum of hundreds of action-exhibits cover the physical sciences and graphic arts. These, together with the Fels Planetarium and public observa-

[7] Report of Committee on Education and Participation in Science, 1939. Yearbook of American Philosophical Society, 1939, pp. 353–364.

[8] Roland S. Morris, *The Friend*, Philadelphia, Pa., 113: 10, 173–174, November 1, 1939.

tory, make it a natural center for amateur interest with twelve such organizations meeting there.

The Wagner Free Institute of Science, founded in 1847, on the other hand, is the only institution in the city where adults may attend free lecture courses at night on chemistry, physics, engineering, botany, geology, geography and zoology. Three amateur clubs also meet here. Further removed from the city, in Media, county seat of Delaware County, is the Delaware County Institute of Science. This unique institution, started in 1833, also bears testimony to the spread of amateur interest in science both in the past and to-day. Here, under volunteer leaders, are enrolled men and women in autonomous groups in geology, mineralogy, foreign languages and other subjects. Other museums in the Philadelphia community available to amateurs scientifically inclined are the Commercial Museum and the University of Pennsylvania Museum, both notable in their specialties. The former is devoted to exhibits of commerce and geography and carries on educational services for the public schools. It also provides a series of free lectures for adults in geography and travel. The University Museum, concerned with archeology and ethnology, conducts research in these fields and maintains outstanding exhibits. It, too, features a free lecture course. From time to time, amateur archeologists and ethnologists have worked as volunteers on the staff.

However, the institutes and museums mentioned are not the only institutional facilities in and around Philadelphia available for stimulating amateur science. In addition, there are extension courses of colleges, adult night schools and other agencies. It must be noted, though, that the science content of such offerings is limited. The city is also rich in library resources of the reference or research type. Thirty-eight of them contain books in the general fields of the sciences. The Bibliographical Planning Committee should bring about cooperation for the most effective use of such valuable resources.

Philadelphia possesses other instrumentalities for broadening interest and knowledge in science. Its Fairmount Park system, consisting of 39 different tracts and areas, comprising a total of 3,838 acres, is the largest natural park region within the boundaries of any city. It offers innumerable opportunities for field studies in natural history. Situated in Fairmount Park are the Zoological Gardens, maintained by the Philadelphia Zoological Society. It is the oldest institution of its kind in the United States with an important collection of animals, whereas its educational program is broad and is an important influence in the city for popularizing science. Also located in Fairmount Park is the city-owned Aquarium and the Horticultural Hall. In and about the metropolis are a number of arboreta and botanical gardens, public or semi-public in function. Largest is the Morris Arboretum in Chestnut Hill, owned and run by the University of Pennsylvania. Finally, as a resource for scientific education and research are the seven observatories in the Philadelphia district accessible to amateurs. In all, there are some 164 separate institutions or other potential centers for amateur use. The American Philosophical Society's committee is now preparing a guide to all these.

Now, turning to those various clubs and societies formed to meet the needs of thousands of leisure-time scientists, we shall appreciate their function more fully after having examined their background. The following statements are based on analysis of 30 of the most active groups devoted to the physical and natural sciences. By means of question-

naires, visits to organizations and conferences, the executive staff has compiled this list. The executive staff consists of Roger Conant, curator of the Philadelphia Zoological Garden, in zoology; Dr. John M. Fogg, Jr., assistant professor of botany of the University of Pennsylvania, in botany; Dr. Serge A. Korff, Bartol Research Foundation, in physics and astronomy; Dr. Edward E. Wildman, of the Philadelphia Board of Public Education, in education and general science; and the executive secretary, W. Stephen Thomas, formerly director of education of the Academy of Natural Sciences of Philadelphia. The following amateur scientific organizations which were studied, together with the total number of members of each, as reported late in 1939, are as follows:

	Organization	*Number of Members*
1.	Aero Club of Philadelphia	130
2.	Amateur Astronomers of The Franklin Institute	50
3.	American Entomological Society	65
4.	American Meteor Society—(In Philadelphia area)	8
5.	Bird Club of Philadelphia	80
6.	Botanical Society of Pennsylvania	120
7.	Burholme Bird Club	35
8.	Comstock Society	85
9.	Delaware County Institute of Science	225
10.	Delaware Valley Naturalists' Union	75
11.	Delaware Valley Ornithological Club	150
12.	Eastern Bird Banding Association	150
13.	Frankford Mineralogical Society	25
14.	Geographical Society of Philadelphia	430
15.	Junior Zoological Society	20
16.	Leidy Microscopical Club	30
17.	Naturalists' Field Club (U. of P.)	30
18.	Pennsylvania Fish Culturists Association	300
19.	Pennsylvania Forestry Association	650
20.	Pennsylvania Parks Association	1,400
21.	Peregrine Club	15
22.	Philadelphia Botanical Club	89
23.	Philadelphia Geological Society	58
24.	Philadelphia Mineralogical Society	127
25.	Philadelphia Natural History Society	46
26.	Philadelphia Council of Camera Clubs	31
27.	Rittenhouse Astronomical Society	205
28.	Society of Natural History of Delaware	126
29.	West Chester Bird Club	60
30.	Wissahickon Bird Club	104
	Total Membership	3,899

With but one exception (the Philadelphia Geological Society whose membership is semi-professional) this list includes amateur groups. For that reason, professional and academic organizations were not considered in this study, though records and statistics concerning them have been gathered by the committee. Illustrations of the professional type are such well-known bodies as the American Association for the Advancement of Science, American Association of Scientific Workers, American Institute of Chemists, American Chemical Society (Philadelphia section), Pennsylvania Chemical Society, American Gem Society and many others. These would not exclude teachers' organizations, clubs and seminars formed in affiliation with the scientific departments of colleges and universities. But all of them are, or should be, interested in amateur scientific endeavor and should be of potential service in giving advice and, where possible, should provide leadership.

In turning to the analysis of the selected organizations grouped above, a prime concern of the committee was to discover the causes motivating the organizing of these bodies. Scrutiny of their constitutions showed that the expressions "to promote interest" in one subject or "to diffuse knowledge" of another were most frequently used. Actual count revealed that 67 per cent. of the thirty clubs considered education of the members and of the public at large as their chief aim. On the other hand, 30 per cent. indicated that orig-

inal investigations in the fields of science concerned came first in the interest of the group. Several organizations expressed this purpose as "the improvement and advancement" of their subject through original research. Only 3 per cent. seemed to put any emphasis on the social features of their meetings.

Activities of the thirty amateur clubs and societies studied fall into eleven different classes. The number of clubs engaged in these activities is shown in the following table:

1.	Meetings	29
2.	Reports by members	28
3.	Lectures and talks by guest speakers	29
4.	Demonstrations, incl. use of pictures, specimens, apparatus	23
5.	Maintenance of scientific collections	12
6.	Field trips	25
7.	Keeping records	19
8.	Publications	12
9.	Maintaining library	12
10.	Exhibitions	11
11.	Owning laboratory or apparatus	1

Any analysis of the sort attempted by the committee would have lacked some worth had it failed to reveal the actual part taken by members in the activities of their respective organizations. This part of the study, based on figures of attendance at meetings, participation in discussion, the making of reports and the attendance on field trips and in other functions, varied to a marked degree. In one instance only 3 per cent. of the membership took part, whereas in two other bodies, each small and selective, almost 100 per cent. of the members participated in amateur activities. However, the average participation for the total number of thirty groups was 47.2 per cent.

Another important fact brought out by the survey was that 85 per cent. of the membership of these clubs and societies in the course of their recreation in science utilized some form of skill or technique. These techniques varied from the ability to identify, classify and prepare many types of organic or inorganic material to the construction and manipulation of apparatus and instruments. The latter included cameras, microscopes, telescopes, radio instruments and even airplanes.

As the effectiveness of most professional scientific research depends upon its availability for use through publication, so, also, in amateur endeavor, publication of original observations, records and other data is a prominent factor. As noted before, 12 clubs, or 33 per cent., issued their own publications, though only 23 per cent. of the total membership actually saw their material in print. The publications ranged from creditable scientific periodicals, often with professional scientists such as museum staff members as editors, to more ephemeral bulletins and newsletters in mimeographed form. But it must be pointed out that these latter served as a medium for stimulating interest and spreading education among the members.

Although, as was previously indicated, approximately 30 per cent. of the various amateur groups emphasized pure research, it is to be remarked that the minutes, publications and other records of the organizations, as well as the scientific collections which are in many cases assembled, represent material of possible use in the promotion of knowledge. Especially does this fact apply to the natural sciences in which the seasonal variations in fauna and flora are recorded by field observers who may be amateur bird students, botanists, entomologists or the like. H. L. Hawkins, already quoted, wrote in this connection regarding amateur groups in Great Britain:

In the matter of research, the greatest contribution (other than encouragement) that can be made by scientific societies comes from their ability to keep, check, and publish records of

transient phenomena. Every recurrent seasonal event in nature invites and often receives accurate observation. . . . In such work the society as distinct from the individual has a special value; for records without independent confirmation are of uncertain use. . . .[9]

One fundamental disclosure of the Philadelphia study was the information concerning the needs of the various organizations in advancing the interests of their members and in promoting and diffusing science. In the course of its survey, the committee found that, although a majority of the groups seemed adequately organized for their own purposes, 56 per cent. of the total would profit by outside help and cooperation. More specifically, there was a need for coordinating programs and activities, exchanging speakers and increasing membership. Also desirable was more varied program material, such as demonstrations of scientific work and the provision of more visual aids in the form of good motion pictures and colored slides. Lastly, there was need to further the original work of members. Sixty per cent. of the organizations expressed the immediate need of new members. Several of the groups gave evidence that if new membership were not secured, it was doubtful if the club or society would long survive.

Several of the groups, more especially those in general natural history, showed a record of more pronounced activity thirty or forty years ago than to-day, with a decided falling off of interest and participation in the last ten years. The situation, however, did not apply to individual amateur naturalists working on their own. An interesting commentary on this condition is the fact that between 1900 and 1920, in the Philadelphia area, there were reported to be some thirty small but active amateur microscopical study clubs. To-day, there are but two. Twenty years ago, there existed in the region five organizations, each with several hundred members, devoted to the study and culture of aquarium fishes. At the present time, the Pennsylvania Fish Culturists Association is the sole representative of this once flourishing amateur interest. Equally significant, though, has been the growth of interest in astronomy and bird study, while in the applied sciences activity in photography and radio operation has accelerated tremendously in the last decade.

In examining the effectiveness of the divers bodies for stimulating amateur science, it was found that the most successful organizations were those which possessed within their ranks one or more scientifically qualified leaders. These moving spirits were not only experts in their subjects but delighted in working with those less informed and had the ability to interpret technicalities in a popular but accurate manner. In this connection, it can be pointed out that some relation with science in its professional aspects has proved continuously healthy for amateurs. That the meeting places of a number of the groups are placed in museums and similar centers has undoubtedly been one of the reasons why amateur science has flourished, not only in Philadelphia but in other communities. The easy access to scientists on academic and museum staffs and the availability of research material in the form of books and collections has done much to spur on the layman to contribute to the accumulation of scientific knowledge. Such relationships need to be strengthened and perpetuated. One means for bringing about this situation would be the formation of informal councils or advisory groups for each of the clubs seriously concerned with science to which qualified professional leaders would be willing to contribute advice and other assistance.

An immediate reaction to the questionnaires sent out by the committee and

[9] *Op. cit.*, p. 263.

the visits of its staff was the favorable attitude toward mutual cooperation. Tangible evidence of this feeling was the spontaneous movement for a council or affiliation of all the various scientific bodies within a thirty-mile radius of Philadelphia. Such an affiliation, semi-professional in nature, has existed in New York City as the New York Academy of Sciences and Affiliated Societies. Two other such councils have just been organized in Buffalo and Rochester, N. Y. In Philadelphia, a meeting of thirty delegates from twenty-five groups included in the survey held a meeting which appointed an organizing committee. The latter, in the spring of 1940, formally launched the Philadelphia Council of Amateur Scientists. This council pledged itself to act as a clearing-house for information, to coordinate the purposes and activities of the groups, to increase membership, exchange program material and to bridge the gap between science and the public.

In reviewing the role of amateur scientific organizations, one further consideration is not to be neglected. All these aggregates of leisure-time scientists, following many different branches of interest, have an important link with their immediate community. They represent groups organized for the mixed purposes of recreation, education and the promotion of knowledge. In this sense they are social agencies. They have, for that reason, a potential relationship to other local groups and organizations. It can readily be seen how schools and general educational bodies and these amateurs might work together to mutual advantage. An instance of this appears in the effective work which might be done with the large number of science clubs in the elementary and high schools, both public and private. These small clubs provide means for intelligent recreation after school hours, for they allow young people to learn about science by making experiments, collecting specimens and data and constructing apparatus. Adult clubs could aid, from time to time, by furnishing speakers and leaders and by affording stimulation through other means. On the other hand, these younger groups possess members who, at a later date, will be highly qualified to join the older organizations. This might be a possible solution to the dwindling membership in some of the adult groups. Another instance of future cooperation exists in the situation regarding the adult evening schools, flourishing in suburban communities around Philadelphia as well as in other localities. These self-organized schools for laymen are in need of practical courses and demonstrations in the pure sciences. But professional sources do not seem adequate to supply material and teaching personnel. Here is a case where local scientific clubs could provide enriched programs and leaders for teaching science and stimulating scientific activities and hobbies among the public. Also, in the field of recreation, such agencies as Boy and Girl Scouts and social welfare groups need trained leaders to supervise nature study, photography, gardening and many other branches which are forms of amateur science. Lastly, the amateur groups, each in its own locality, can serve as important interpreters of science not only through many formal educational means but through the example of their individual members.

UNIFYING SCIENCE IN A DISUNIFIED WORLD

Prepared for the International Institute for the Unity of Science
by M. B. Singer and A. Kaplan

The first week of the European war coincided with the convening of an international group of distinguished scientists and philosophers to participate in the Fifth International Congress for the Unity of Science held at Harvard University. That forces for unification should be called out by a world in which disunification is wide-spread is not without historical parallel. Welcoming the two hundred delegates from nine countries, President Conant of Harvard called attention to the similar circumstances under which the Royal Society of England was founded three centuries ago "in a period of civil and religious strife." And to-day the scientist is even more closely concerned with the world around him, for science is frequently blamed and criticized for the part it allegedly played in bringing about the contemporary chaos.

The discussions at the congress exhibited the activities of the unity of science movement as proceeding simultaneously along three fronts: first, the coordination of the special sciences with one another through a coordination of the concepts and principles of the different sciences; second, making available the results of such unification for more efficient application of various sciences to the solution of practical problems in engineering, agriculture and medicine; third, applying the content, method and outlook of science to formal and adult education.

The last two phases were given special emphasis at the congress because of the influence American pragmatists and operationalists have had on the movement as a whole. This influence was explicitly acknowledged at the Harvard Congress by a paper commemorating the centenary of the birth of Charles Peirce, the founder of American pragmatism, and by an appreciative letter to John Dewey in honor of his eightieth birthday. The international movement, however, owes its origins to two groups of philosophers and scientists who met informally in pre-Hitler Berlin and Vienna to discuss the works of Ernst Mach, Bertrand Russell and Ludwig Wittgenstein. Since that time, the voluntary or forced expatriation of many of the Germans and Austrians has minimized the importance of geographical boundaries in the movement.

Although it is scarcely five years since it was officially organized, the International Institute for the Unity of Science is fast becoming responsible for a major movement in the scientific world. The Harvard meeting was held under the sponsorship of the American Association for the Advancement of Science, the American Philosophical Association, the Philosophy of Science Association, the History of Science Society and the Association for Symbolic Logic. The last two organizations, sharing members and interests with the institute, held joint sessions with the congress proper.

In the investigation of scientific method the unity of science movement has set itself the task of constructing, with the help of mathematics and symbolic logic, the skeleton of an exact language in which the logical connections of terms and laws of the different sciences could be precisely expressed. One of the innovations of the Harvard Congress was that

the language of the social sciences was given as much attention as that of the physical sciences.

The Harvard Congress was also unique in enlisting the interest and active co-operation of practical technicians to discuss the applied and social aspects of science. At the two sessions devoted to this subject papers were read by professional engineers and a representative of the U. S. Department of Agriculture. The discussions in this field were exploratory in nature and inaugurated consideration of problems in the history and sociology of science which will undoubtedly assume increasing importance in the process of unifying the sciences.

Of most significance to the general public are the implications of the unity of science for education. These were partly traced in a paper by an educator urging that much of the present aimlessness and incoherence in American education could be eliminated without imposing doctrinaire regimentation by utilising the resources of the unity of science movement, and particularly by introducing into scientific curricula, even at high-school and elementary levels, a study of the history and logic of science.

For many members of the congress, especially for Dr. Otto Neurath, its permanent secretary, these implications reach beyond the classroom. He and his associates in the unity of science movement want to disseminate a scientific outlook among all literate adults. Ours is a scientific age and almost every one has some notion of what science is about. But the frequent misinterpretations and unwarranted extrapolations of scientific findings promulgated by careless or incompetent popularizations have created the important and difficult function of interpreting the results and methods of science to a large and interested lay public.

An essential stage in the performance of this function is to interpret the technical language of the sciences in terms of every day language. As Dr. Neurath formulates this task: it should be possible to translate Einstein's theory of relativity into a taxi driver's vernacular. The work that has already been done on the structure of scientific language makes this a far less quixotic objective than appears at first sight. Together with the pictorial techniques for presenting statistical data (Isotype), to which Dr. Neurath has also made important contributions, this work offers vivid and accurate tools to the adult education movement.

To promote this and the other phases of its activities the International Institute for the Unity of Science holds annual congresses, publishes a *Journal of Unified Science* (W. P. Van Stockum and Zoon, Holland; American agents: University of Chicago Press), directs the publication of monographs and books contributing to the movement through its "Library of Unified Science," and has just initiated a far-reaching project of constructing an "Encyclopedia of Unified Science" (University of Chicago Press), which will embody the progressive attainments of the movement.

The unity of science movement promises to become a fit expression of the twentieth-century scientist's social conscience by promoting mutual understanding among scientists, clarifying the nature of science—both in itself and as a force in human culture—and making possible smooth and accurate transitions from the professional world of the scientist to the everyday world of scientist and layman alike.

BOOKS ON SCIENCE FOR LAYMEN

FOUNDERS OF CHEMISTRY[1]

THOSE who enjoyed Mr. Haynes's entertaining sketches of the pioneers of American chemical industry, as they appeared serially in "Chemical Industries," have now the opportunity of re-reading these interesting biographies in attractive book form. After a preliminary sketch of the many-sided efforts of John Winthrop, Jr., to exploit the undeveloped chemical resources of colonial New England, the author passes over the next century and a half in order to take up the real program of his volume, which is to give a vivid account of the founders of some of the leading chemical industries of the United States. These founders in nearly all cases established chemical dynasties whose histories through several generations of family control constitute the most interesting feature of the present volume. Details of business developments and transfers are interspersed with an abundance of anecdotal material so that the interest of even the most casual reader is well sustained. The sketches of the Rosengarten, Kalbfleisch, Mapes, Grasselli, Warner, Klipstein and other chemical founders all show similar traits of business capacity and enterprise not only by native sons of colonial ancestry but by later immigrants of British, French, Dutch, German and Italian origin. No small part of the early developments in American science and industry is due to the transplanting of European ideas and practices to the more stimulating environment of the new republic. The book is recommended not only to chemists and chemical manufacturers but to those who are interested in the origins of domestic industries and in the story of human relations.

C. A. BROWNE

[1] *Chemical Pioneers.* By William Haynes. Illustrated. xvi + 288 pp. $2.50. 1939. D. Van Nostrand Company.

FLOWERS OF THE DESERT[1]

JAEGER'S "Desert Wild Flowers" makes one want to pack up the old flivver and start out to find the plants he pictures. Jaeger interprets "flowers" very broadly to include Piña and Palm as well as Cactus and Castilleja. The book is in fact a flora of the Southwestern Deserts, though the author departs from the formal order of a flora and dispenses with keys—which the reviewer would wish to have. But the species are figured, mostly with drawings which by lines or with simple shading catch and portray the essential features of the plants with unusual skill. To these are added a few photographs softly done on matte paper in a style at times almost worthy of a Corot.

It is easy to see that Dr. Jaeger is a teacher—though a zoologist rather than a professed botanist—for he advises his readers "to carry the book with them into the desert along with a box of colored pencils so that they may fill in the colors directly from the flowers. This if carefully done will not only greatly increase the attractiveness of one's copy of the book but will also impress the plant more firmly on one's memory"; and the paper of the book was in fact carefully chosen to take such color. Few users, however, will have either the patience or the skill necessary to color the fine detail drawings successfully. It is so much easier in these days to take Kodachromes far more accurate than hand-colored prints. This leads the reviewer to hope that the time is not far distant when the cost of reproducing pictures in color will come down to a point where every such manual will be illustrated in color. For a generation or more Europe has had popular floras with the flowers shown in color. Is it not

[1] *Desert Wild Flowers.* By E. C. Jaeger. Illustrated. 322 pp. $3.50. March, 1940. Stanford University Press.

time that America reached the same stage?

ROBERT F. GRIGGS

THE MIND GROWS UP[1]

THE present volume is the third edition but first English translation of a well-known work on comparative developmental psychology, written from the Gestalt point of view. The concept of comparative development is taken as fundamental, being illustrated by genetic parallelisms of behavioral development as observed from data in the fields of child psychology, social and ethnopsychology and anthropology, animal psychology and psychopathology. The book should be of especial concern to students of these fields, as well as to those interested in a systematic psychological science.

The author begins by contrasting the "mechanistic" and "organic" (*Gestalt*) approaches to psychological phenomena. The former term is used to denote any analytic or reductionistic schema for behavior description, as found in various forms of associationism, behaviorism or other stimulus-response psychologies. Werner cites the usual Gestalt arguments against this approach, and adopts the second or "organic" view, with its emphasis upon the priority of totalities or configurations. Werner's position is thus typical of the German *Struktur* or *Gestalt* psychology, with its historically related movements of the *Gestalt-* or *Komplexqualität*, the *Personalistik* and the *Geisteswissenschaften*. The central tenet of these various movements is that the study of mental *patterns* or *Gestalten* should take precedence over the more analytical study of elements, events or stimulus-response coordinations. Thus Werner states (p. 15):

> Development cannot be symbolized by a continuous, mathematically conceived line, but rather must be thought of in the form of typical mental patterns, with the relatively higher levels being understood as innovations emerging from the lower.

Werner then reports extensive data from child psychology, social psychology and anthropology, animal psychology and psychopathology, illustrating the "primitive character" of behavior in each of these fields. The material is classified as follows: (1) primitive sensori-motor, perceptual and effective organization, (2) primitive imagery, (3) primitive notions of time and space, (4) primitive action, (5) primitive thought processes. The author purports to find the same structural principles of mental organization to hold in the mental life of children, "primitive" peoples, animals and schizophrenics. Primitive mental life, in such cases, is held to be syncretic, diffuse, indefinite, rigid and labile. Animism, magic and synaesthesia are three illustrative examples from different fields. The course of mental (as well as biological, *e.g.*, neural) development illustrates increasing differentiation, subordination of parts and hierarchization. Increasing differentiation yields a "plurality of mental levels," the genetically higher levels being characterized as not syncretic, but discrete; not diffuse, but articulated; not indefinite, but definite; not rigid, but flexible; not labile, but stable.

Criticisms of the book can best be directed against (1) the loose use of terms, many of which can neither be operationally defined nor logically derived from others capable of operational definition, and (2) the Gestalt bias and complete disregard for other possibilities of interpretation. Thus, for example, there is no discussion whatever of the phenomena of conditioning, and no use is made of conditioned response principles in the interpretation of the data. In fact, there

[1] *Comparative Psychology of Mental Development.* By Heinz Werner. 510 pp. 1940. Harper and Brothers.

is no reference to conditioning in the index, and no apparent reference to the extensive work in this field in the otherwise excellent bibliography of 751 items. The obvious relevancy of conditioned response principles to many if not most of the data is illustrated by the following passage, taken as a random illustration from the discussion of "primitive abstraction" (p. 238):

> Again, concrete abstraction accounts for many verbal expressions for the qualities of objects the adult names for which the child has yet to learn. He may designate colors by naming familiar objects which characteristically exhibit these colors. For example, a boy four and a half years old is sorting color cards. He knows only the names "red," "blue," "white," and "black." When asked for the name of the yellow card he says, beaming with triumph: "The mail box!" (Australian mail boxes are yellow.) According to Descoudres' report there are small children who designate "brown" by "chocolate," "white" by "chalk," and "blue" by "pen-box." This is concrete abstraction. The imagined objects and the colored test cards together build up a configuration in which color is the dominant quality-of-the-whole.

Could Pavlov himself have furnished better illustrations of conditioning? And how much more precise and experimentally verifiable than the configural interpretation!

In spite of these serious limitations, however, the volume remains an excellent sourcebook of comparative developmental material. There is also a much-needed emphasis upon the relations between comparative developmental and general experimental psychology. For such methodological "insights" as well as for the extensive source material, the book should be read by every serious student of human and animal behavior.

JOHN P. FOLEY, JR.

MEN AND STARS[1]

THERE is no other book on, or rather relating to, astronomy similar to this one. Instead of directly discussing what has been learned about the universe beyond this earth, it meanders leisurely in and out of various subjects, some of which at first thought might not appear to be connected closely with the stars. In these excursions the authors at times are in the mythological days of Mesopotamia or Egypt; at others, in the beginnings of science in Greece or China; at others, on the frontiers of profound theories with Newton and Einstein.

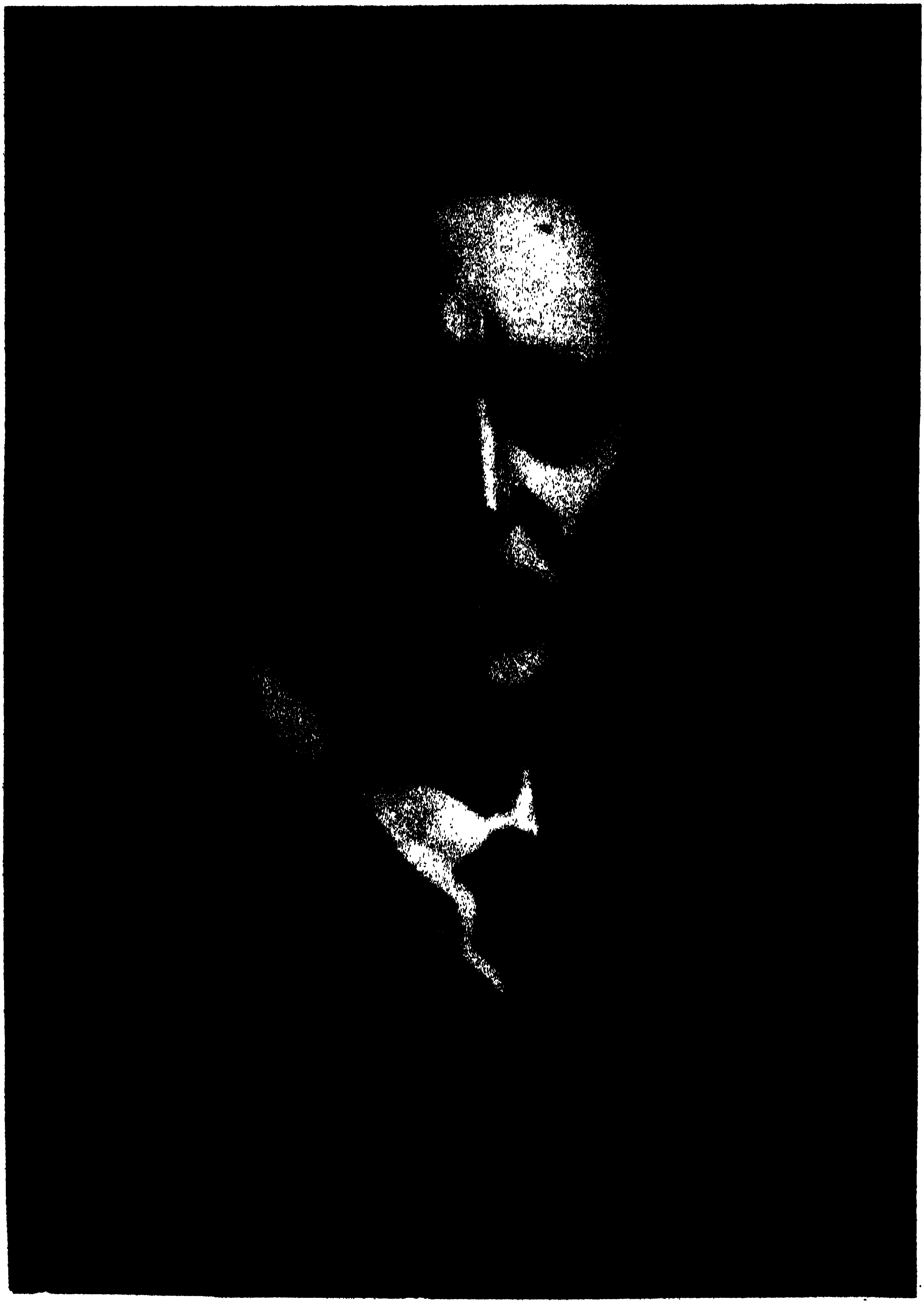
Although the authors wander widely, their paths are not aimless. Instead, they have realized more fully than most writers how completely the somewhat austere frameworks of the astronomy of the professional scientists has been clothed by the masses of men with thousands of vague beliefs that together form substantial mass philosophies. They have written not only of the stars but much about men and their ideas of the cosmos.

The style of the authors is clear, entertaining and often really delightful. Many of their paragraphs are enriched with apt quotations from the writings of authors ranging from Homer to Lewis Carroll. Since they have limited their discussions largely to such subjects as the seasons, eclipses, constellations and navigation, to subjects which have been of interest since antiquity, many current astronomical problems are only briefly considered or omitted entirely. For example, the nature of the stars and the structure of the galaxy are touched rather lightly, though quite clearly and correctly. Extended expositions of what is known about such things would be severe and quite out of harmony with leisurely and friendly descriptions of familiar objects and of ideas mellowed by age.

"Stars and Men" is an excellent book and is deserving of a wide circulation.

F. R. M.

[1] *Stars and Men.* By Stephen A. Ionides and and Margaret L. Ionides. Illustrated. xvii + 460 pp. $4.00. 1939. Bobbs-Merrill.



HANS ZINSSER

PROFESSOR OF BACTERIOLOGY AND IMMUNOLOGY, HARVARD MEDICAL SCHOOL, WHO DIED ON SEPTEMBER 4, 1940, AT THE AGE OF 61 YEARS.

THE PROGRESS OF SCIENCE

HANS ZINSSER—SCIENTIST AND HUMANITARIAN

THE death of Hans Zinsser leaves many voids in the intellectual life of to-day. He was a distinguished scientist, an important commentator on medical education, a soldier and expert in military sanitation, an author and poet of great ability and popular appeal.

Reared in a family of great cultural attainments, his early education was somewhat unorthodox, but it gave him a substantial training in and an abiding love for music, art and literature. Many trips abroad (over twenty before his formal education was completed) and subsequent travels in pursuit of professional interests and duties in many countries—Germany, France, Serbia, Africa, Russia, Mexico and China—made him, because of his humanism, a true cosmopolite.

Until the summer of 1938 when the symptoms of his illness became apparent, his physical vigor and endurance had been great and showed no effect of age; his intellectual powers remained unimpaired to the end. We may only speculate over the possibilities of productivity in many directions which disappeared when that matured combination of great experience and a many-facetted brilliant mind ceased to operate.

He was born on November 17, 1878. He received his A.B. degree in 1899; his A.M. and M.D. degrees in 1903—all from Columbia University. Honorary Sc.D. degrees came from Columbia in 1928, Western Reserve in 1931, Lehigh in 1933 and from Harvard and Yale in 1939. He was, in turn, professor of bacteriology and immunology at Stanford University, 1910–1913, Columbia University, 1913–1923, and Harvard University, 1923–1940.

He accompanied the American Red Cross Sanitary Commission to Serbia in 1915, as bacteriologist. He served in the United States Army Medical Corps, attaining the rank of colonel, from 1917 to 1919. He was sanitary commissioner for the League of Nations to Russia in 1923. He was exchange professor from Harvard to the University of Paris in 1935, and to Peiping University in 1938. He was a member of 36 scientific societies, including the Association of American Physicians, American Philosophical Society, American Academy of Arts and Sciences and the National Academy of Sciences. His decorations were—Distinguished Service Medal, U. S. A.; Légion d'Honneur, France; Order of St. Sava, Serbia.

Dr. Zinsser's scientific work was almost wholly in the field of immunology and his researches have contributed many important elements to the structure of that science as it stands to-day. He was a bold and versatile investigator of problems concerning tuberculosis, syphilis, pyogenic diseases and the pathogenic filtrable viruses. From 1930 on he was occupied almost wholly with the many problems concerned with endemic and epidemic typhus fevers—etiology, transmission, immunology and epidemiology—to all of which he made notable contributions. His last success in the typhus field was the development of methods practicable for the mass production of vaccines for typhus fever and, incidentally, for Rocky Mountain spotted fever.

He is appraised in scientific circles as one of the outstanding bacteriologists and immunologists of his time. The public knew him best through his two delightfully written books, "Rats, Lice and History" (1935) and his autobiography, "As I Remember Him; The Biography of R. S." (1940). Medical students throughout the world know of him through his text-books of bacteriology and immunology, both of which have gone through many editions and translations into other languages.

In university circles, the breadth and

depth of his knowledge brought him contacts with the best minds in diverse fields of learning. He was an inspiring and enthusiastic teacher of medical students. A leader in research, he attracted students from many countries; they received from him education in many things outside of science because he discoursed freely with all his associates and was wholly devoid of academic affectation.

His was a sensitive nature, quick to respond in defense or aid, wrath or sympathy, as occasion warranted. As Professor Walter B. Cannon has said: "The wide range of his interests, his sense of humor, his skill as a musician, his exuberant spirits and infectious enthusiasm and his warmly affectionate nature made him a delightful companion and, to those who knew him well, one of the choicest of friends."

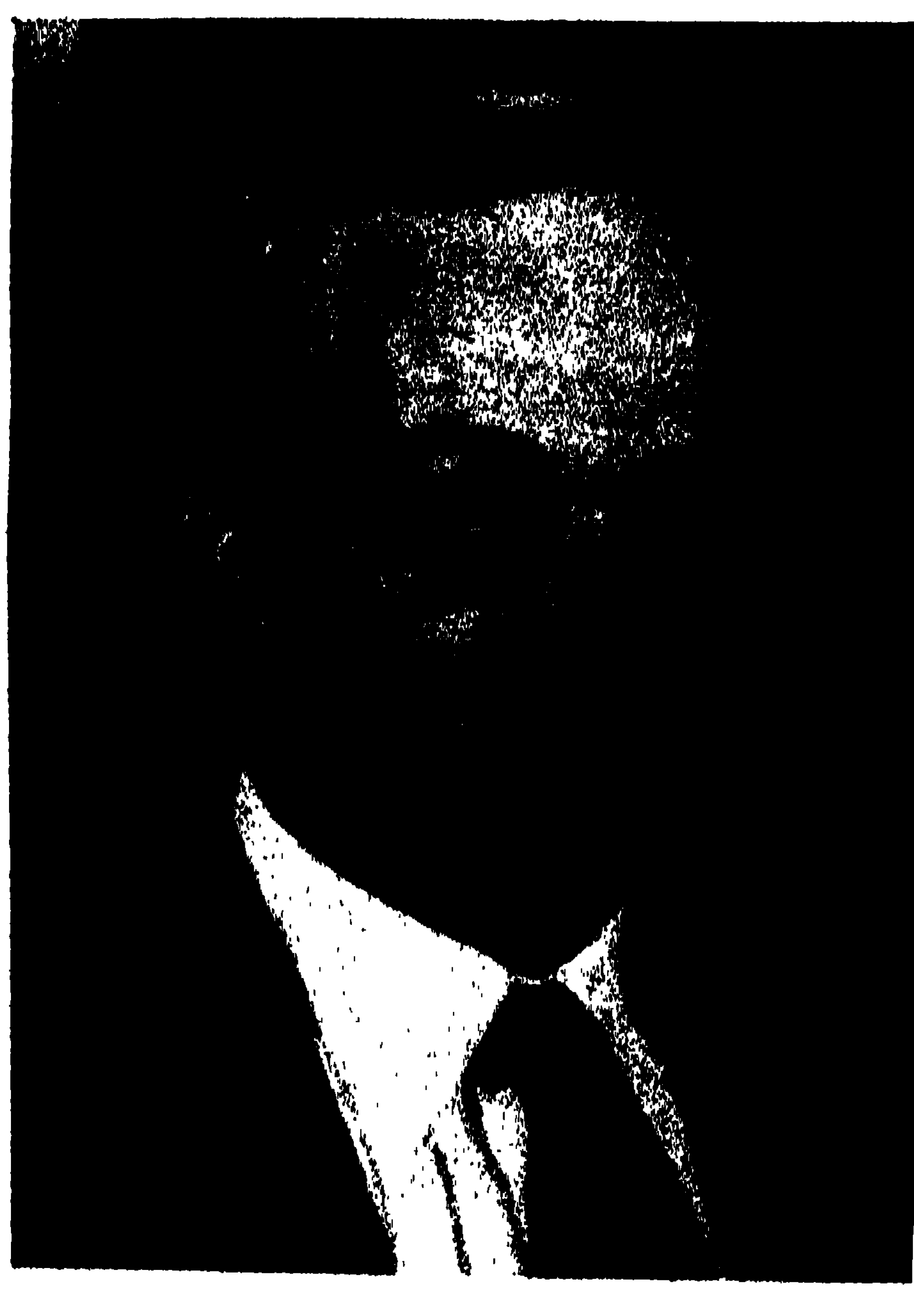
S. B. Wolbach

Harvard Medical School

THE AMERICAN ASSOCIATION ADVANCES SCIENCE

On the general program of the meeting of the American Association for the Advancement of Science held in Philadelphia from December 27 to January 2, the titles of more than two thousand addresses and papers appear. It is difficult to visualize such a volume of scientific contributions. If the papers were presented sequentially before the association as a whole, and if the average length of time required to read a paper were fifteen minutes, the meeting would continue more than 500 hours, or two months at eight hours per day. Consequently, it is necessary to hold many sessions simultaneously; in fact, as many as forty-five are to be held at one time.

Two distinct kinds of sessions are held at the meetings of the association. There are sessions at which specialists present before other specialists in the same field the results of their most recent investi-



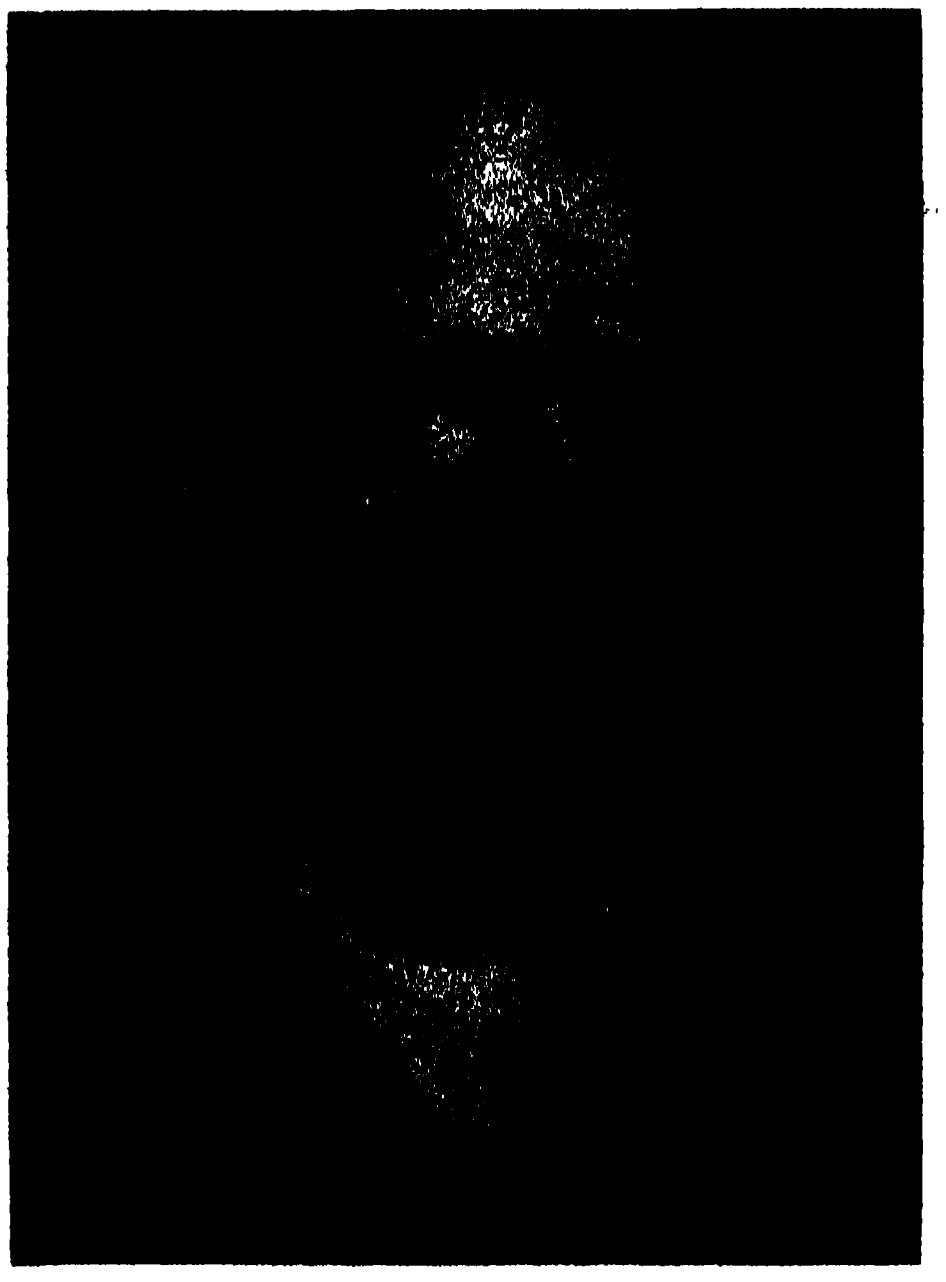
DR. A. B. COBLE

PROFESSOR OF MATHEMATICS, UNIVERSITY OF ILLINOIS; CHAIRMAN OF THE SECTION ON MATHEMATICS.

DR. GEORGE SCATCHARD

PROFESSOR OF CHEMISTRY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; CHAIRMAN OF THE SECTION ON CHEMISTRY.

ROBERT R. McMATH
DIRECTOR, MCMATH-HULBERT OBSERVATORY, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION ON ASTRONOMY.

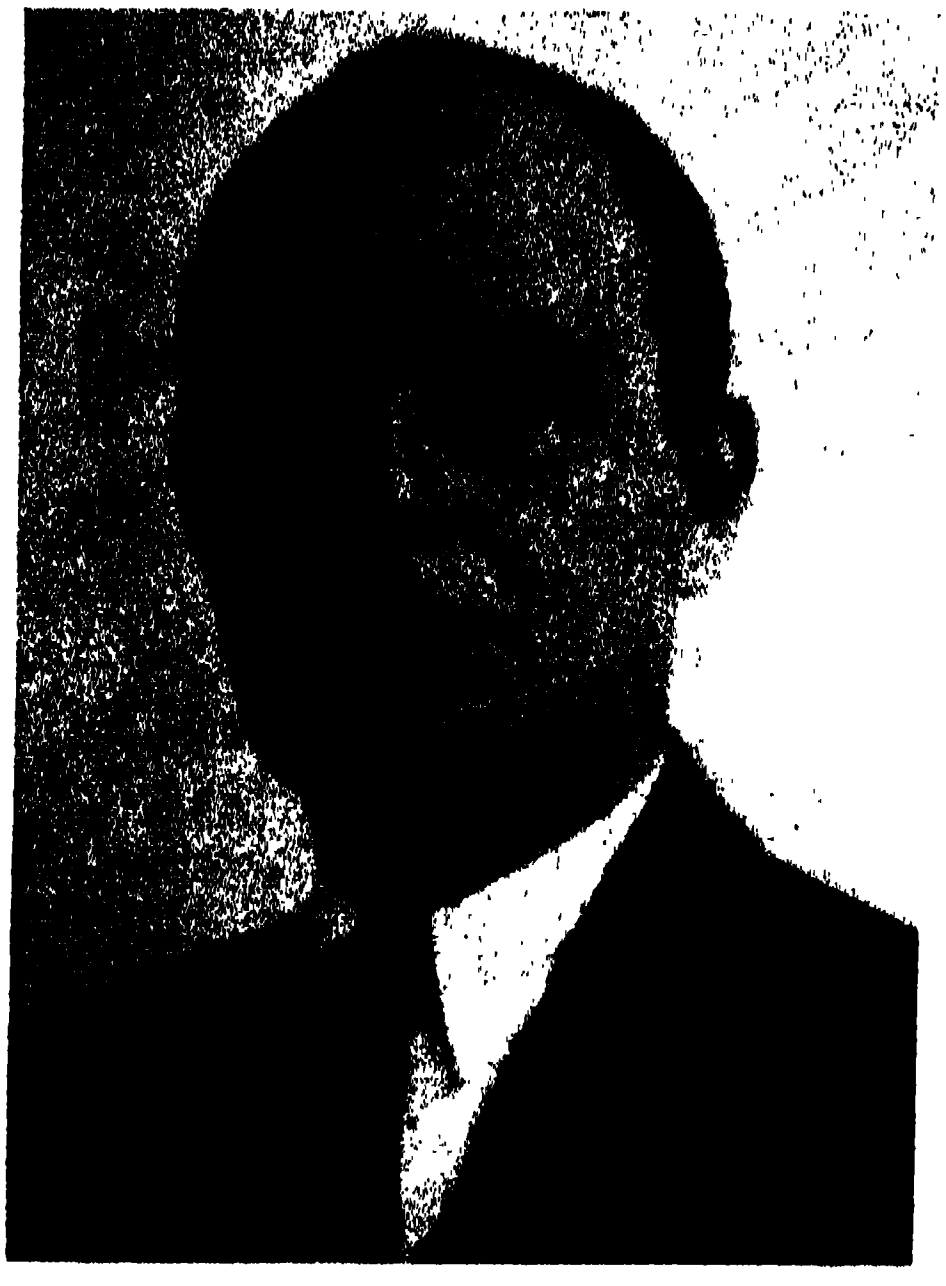


DR. LEON J. COLE
PROFESSOR OF GENETICS, UNIVERSITY OF WISCONSIN; CHAIRMAN OF THE SECTION ON ZOOLOGICAL SCIENCES.

gations. There are other sessions at which distinguished scientists present surveys of rather broad fields of science. The former, roughly speaking, are analyses, while the latter are syntheses. Science marches in two columns, each of which is necessary for the continued advance of the other.

As I have said, there are sessions for the presentation of technical papers by specialists. These sessions are analytic in character because they pertain to one of the narrow fields into which science has been analyzed. When the association was founded ninety-two years ago, science consisted of natural philosophy and natural history. Natural philosophy, generally speaking, included the mathematical and physical sciences; natural history, the biological sciences. Very soon subdivisions of these fields were organized. Now the association has fifteen sections, including the humanities—if the word has any definite meaning. But this is not all; one hundred

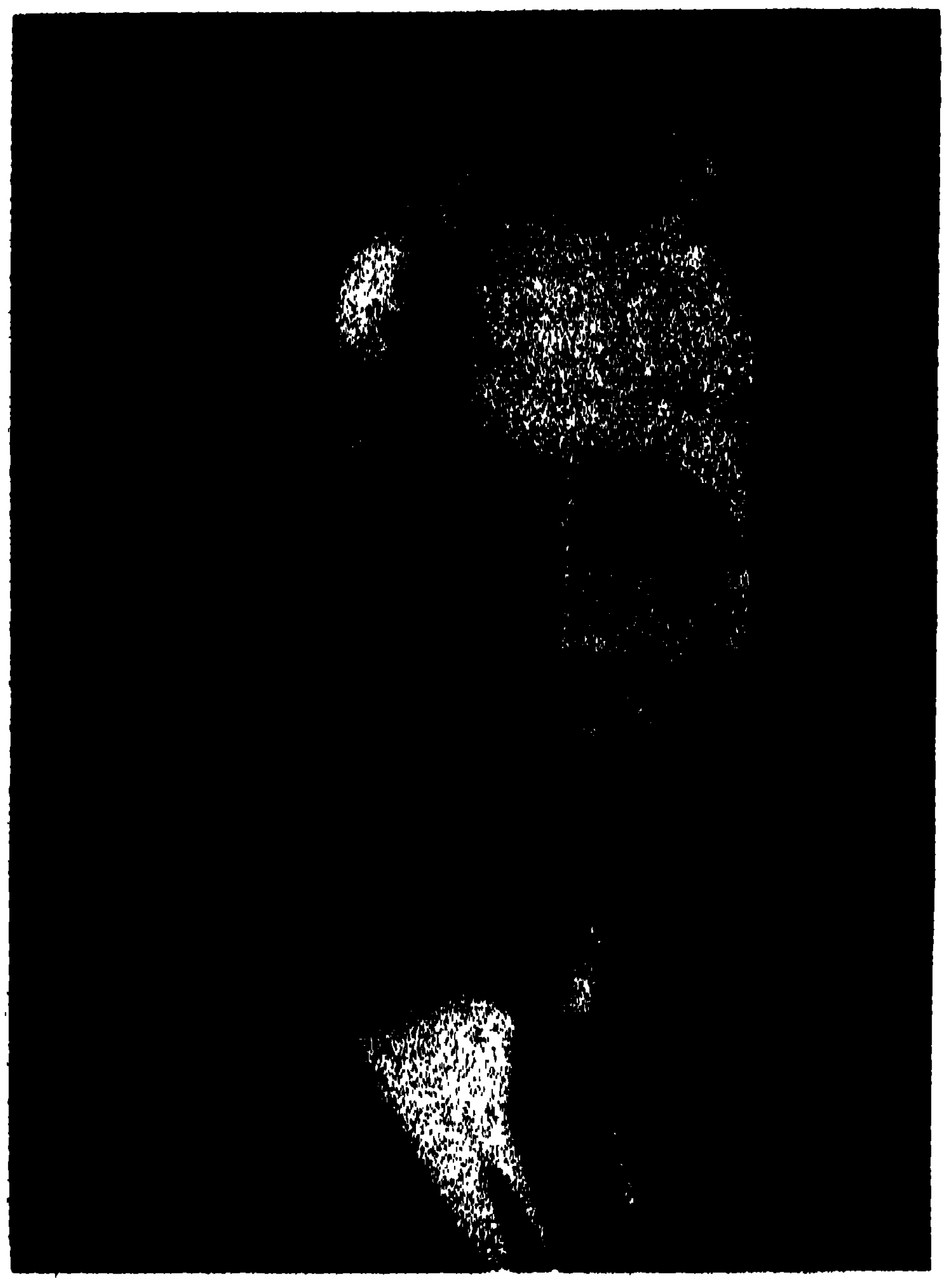
M. L. FERNALD
FISHER PROFESSOR OF NATURAL HISTORY, HARVARD UNIVERSITY; CHAIRMAN OF SECTION ON BOTANICAL SCIENCES.



DR. W. DUNCAN STRONG
ASSOCIATE PROFESSOR OF ANTHROPOLOGY, COLUMBIA UNIVERSITY; CHAIRMAN OF THE SECTION ON ANTHROPOLOGY.

DR. KARL M. DALLENBACH
PROFESSOR OF PSYCHOLOGY, CORNELL UNIVERSITY; EDITOR, *American Journal of Psychology*; CHAIRMAN OF THE SECTION ON PSYCHOLOGY.

and seventy-four other scientific societies are affiliated with the association, many of which meet with it regularly. They range from societies organized for the advancement of such universally known subjects as astronomy and physics to such recently recognized subjects as rheology, psychometry and photogrammetry. A wag once said that specialists in such narrow fields are scientists who learn more and more about less and less. There is some truth in the quip, but in



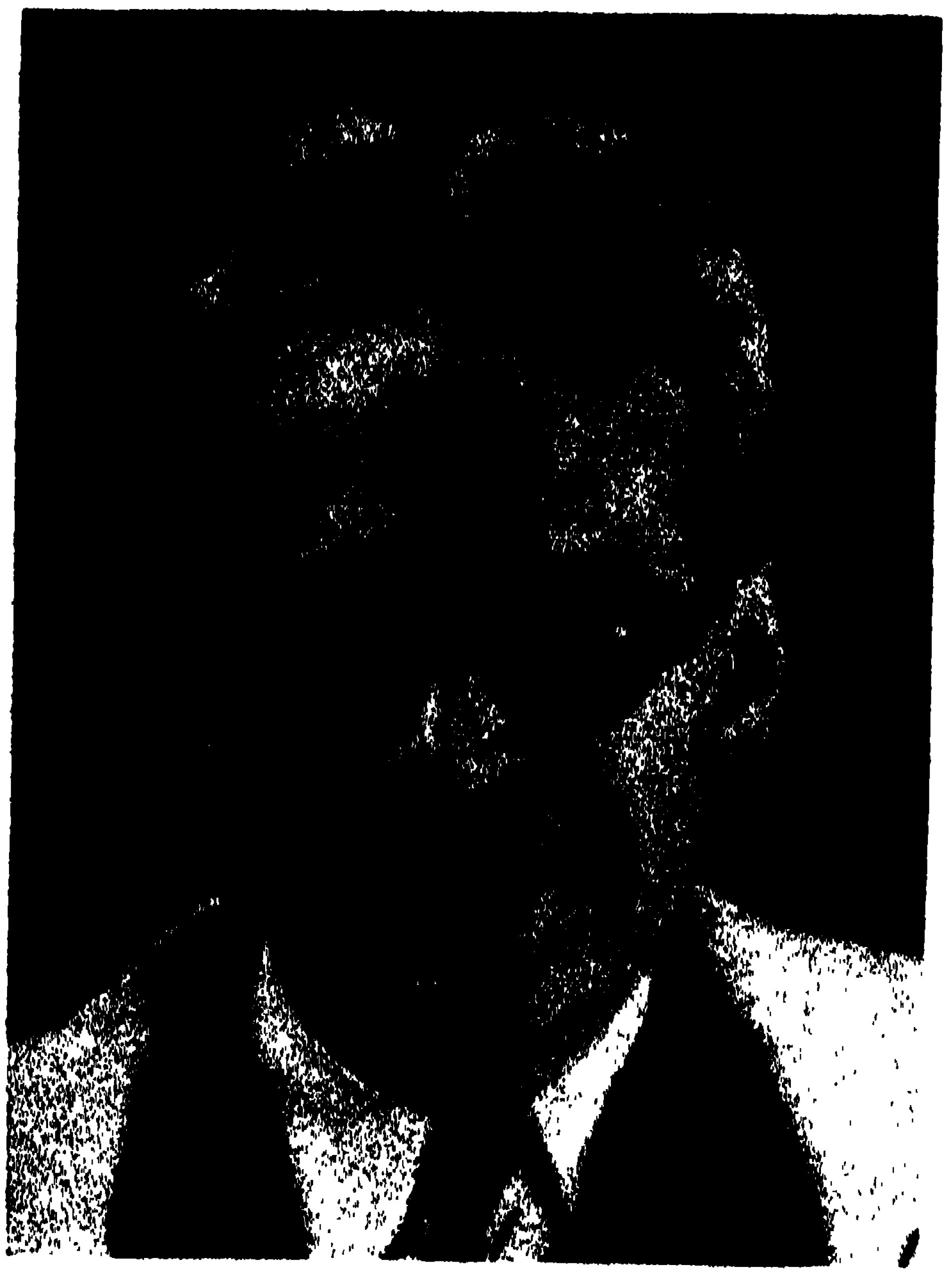
DR. HOLBROOK WORKING
ECONOMIST, FOOD RESEARCH INSTITUTE, STANFORD UNIVERSITY; CHAIRMAN OF THE SECTION ON SOCIAL AND ECONOMIC SCIENCES.

fairness all the emphasis should be placed on the "more and more."

It is the other aspect of science, the synthetic, as it appears in the meetings of the association, which I wish especially to consider here. In addition to the general sessions, open to all scientists and the general public as well, there are formal syntheses in special fields by men who have achieved distinction in them. Each of the fifteen sections of the association has a chairman for one year who

is also vice-president of the association. Upon retiring from office each vice-president delivers an address upon some subject in the field of his section. The retiring presidents of the affiliated societies also usually deliver formal addresses before their respective societies or before joint sessions of their societies and of societies in related fields.

As might be expected, the addresses of the vice-presidents of the association and of the presidents of affiliated societies are generally synthetic in character.

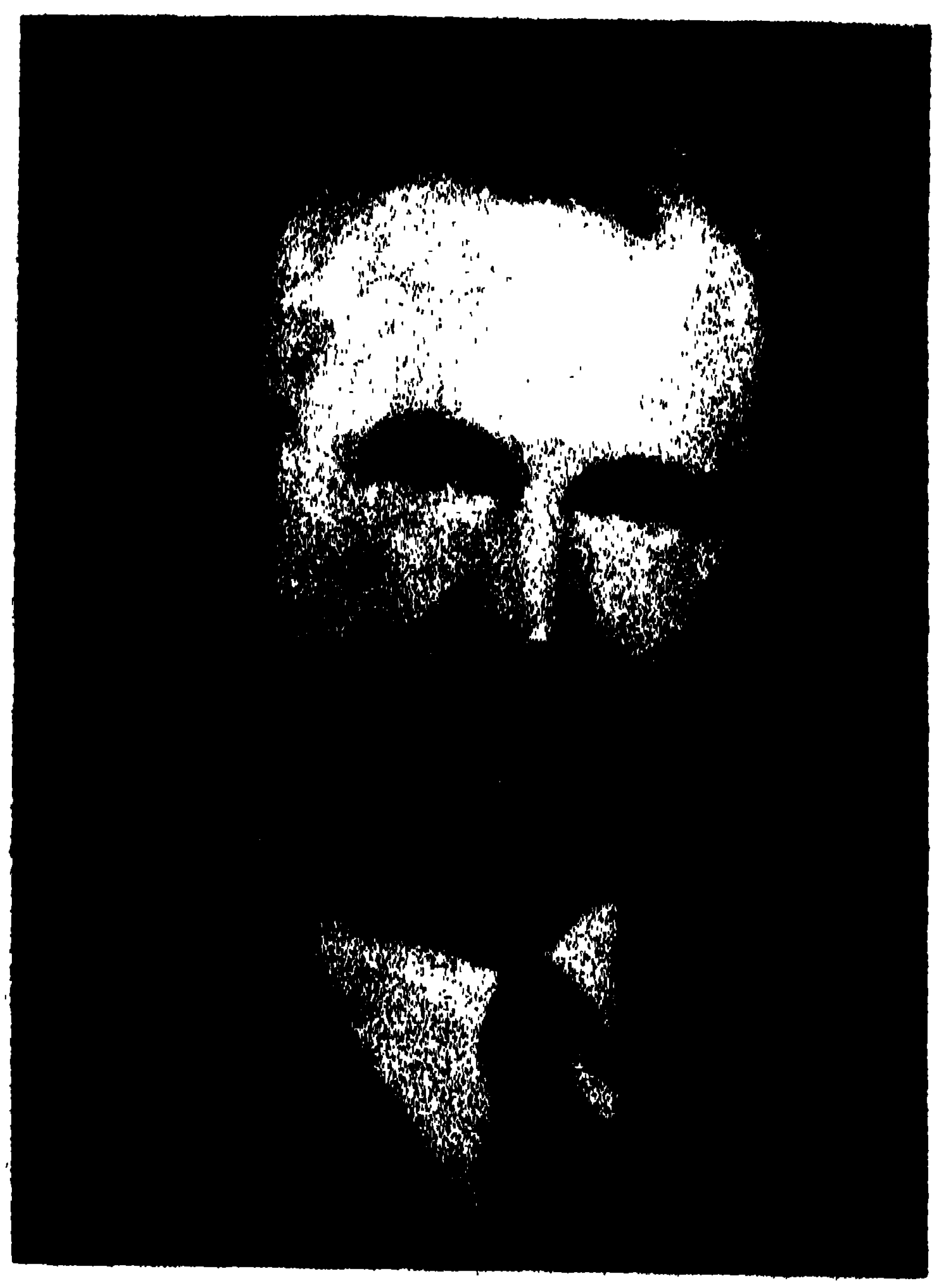


DR. CHAUNCEY D. LEAKE
PROFESSOR OF PHARMACOLOGY, UNIVERSITY OF CALIFORNIA MEDICAL SCHOOL; CHAIRMAN, SECTION ON HISTORICAL AND PHILOLOGICAL SCIENCES.

Syntheses are not simply enumerations of facts and theories in some field. They are coherent organizations of data and theories in special fields. They develop the inter-relations among the data and theories and often their relations to other fields of science and, in these days, to the complex problems of human relations.

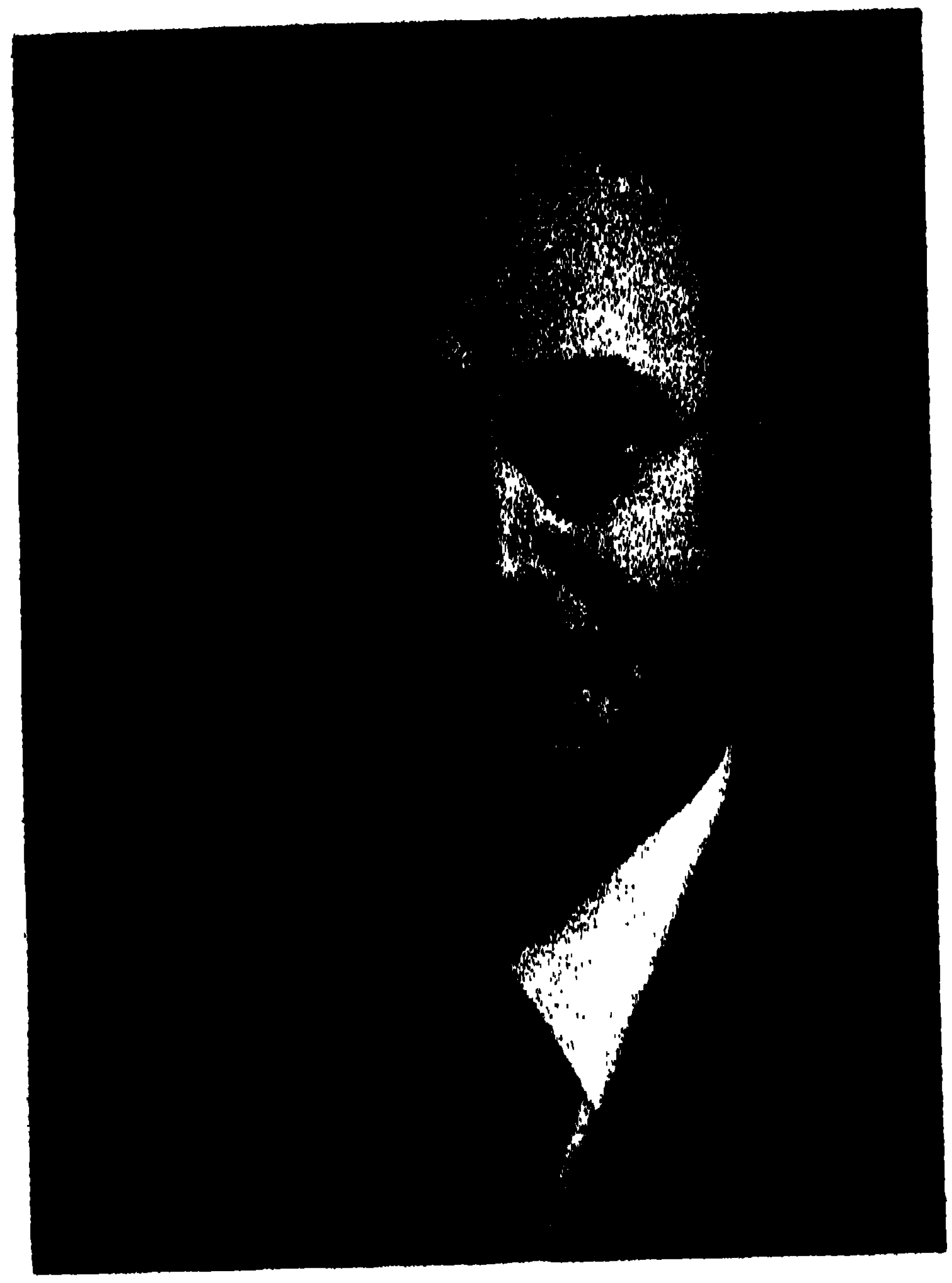
Photographs of the retiring vice-presidents of the association are reproduced

R. L. SACKETT
EMERITUS DEAN OF ENGINEERING, PENNSYLVANIA STATE COLLEGE; CHAIRMAN OF THE SECTION ON ENGINEERING.



DR. PAUL R. CANNON
PROFESSOR OF PATHOLOGY, UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION ON MEDICAL SCIENCES.

DR. W. H. CHANDLER
PROFESSOR OF POMOLOGY, AND ASSISTANT DEAN, UNIVERSITY OF CALIFORNIA; CHAIRMAN OF THE SECTION ON AGRICULTURE.



DR. E. J. ASHBAUGH
DEAN OF THE SCHOOL OF EDUCATION, MIAMI UNIVERSITY; CHAIRMAN OF THE SECTION ON EDUCATION.

in this issue. They were nominated by their sections as being among the leaders of American science in their respective fields, and they were elected by the council of the association. The titles of their addresses are given in the General Program of the meeting. Representing, as they do, every principal field of the natural and social sciences, their addresses are a cross section of science at the present time.

Every day we read in the daily press that the present is a critical time in the world's history and every evening we hear, if we listen, the same sentiments expressed over the radio. Perhaps it is a critical period in which we live. But on the whole scientists contemplate it without hysteria. For every unfavorable influence that can be mentioned, they can name two new ones that are favorable. The statement can be illustrated by the destruction of human life. The war is taking a considerable number of lives directly and probably a greater number by malnutrition. But at its worst the destruction is not comparable to the plagues that once swept over the world. Even the reduction in infant mortality during the past forty years more than offsets any prospective loss of life in the present war, and the general improvement in diet will more than cure the consequences of temporary undernourishment. The proof of these statements lies in the rapid general increase of populations throughout the western world and in the striking improvement in human statures, at least in America.

The vice-presidents of the association are excellent representatives of scientists who regard mankind and its present troubles with the perspective of a knowledge of the long history of the earth and of the life that has evolved on its surface. They are aware of the great tragedies the world has witnessed, and of its marvelous triumphs as well. From this vantage point of knowledge they look with steady eye at the evils of a day.

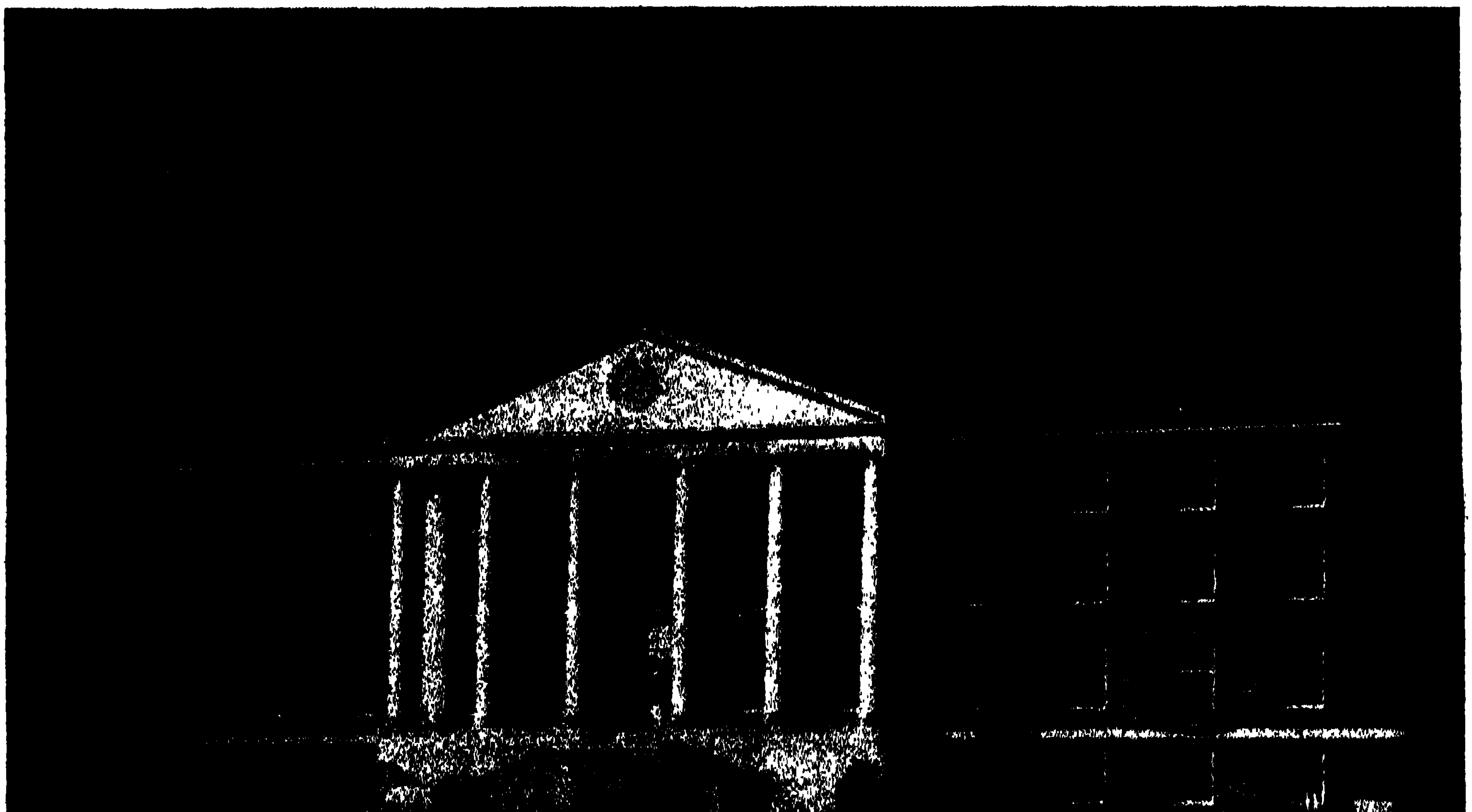
F. R. MOULTON,
Permanent Secretary

CONTRIBUTIONS TO PUBLIC HEALTH OF THE FEDERAL GOVERNMENT

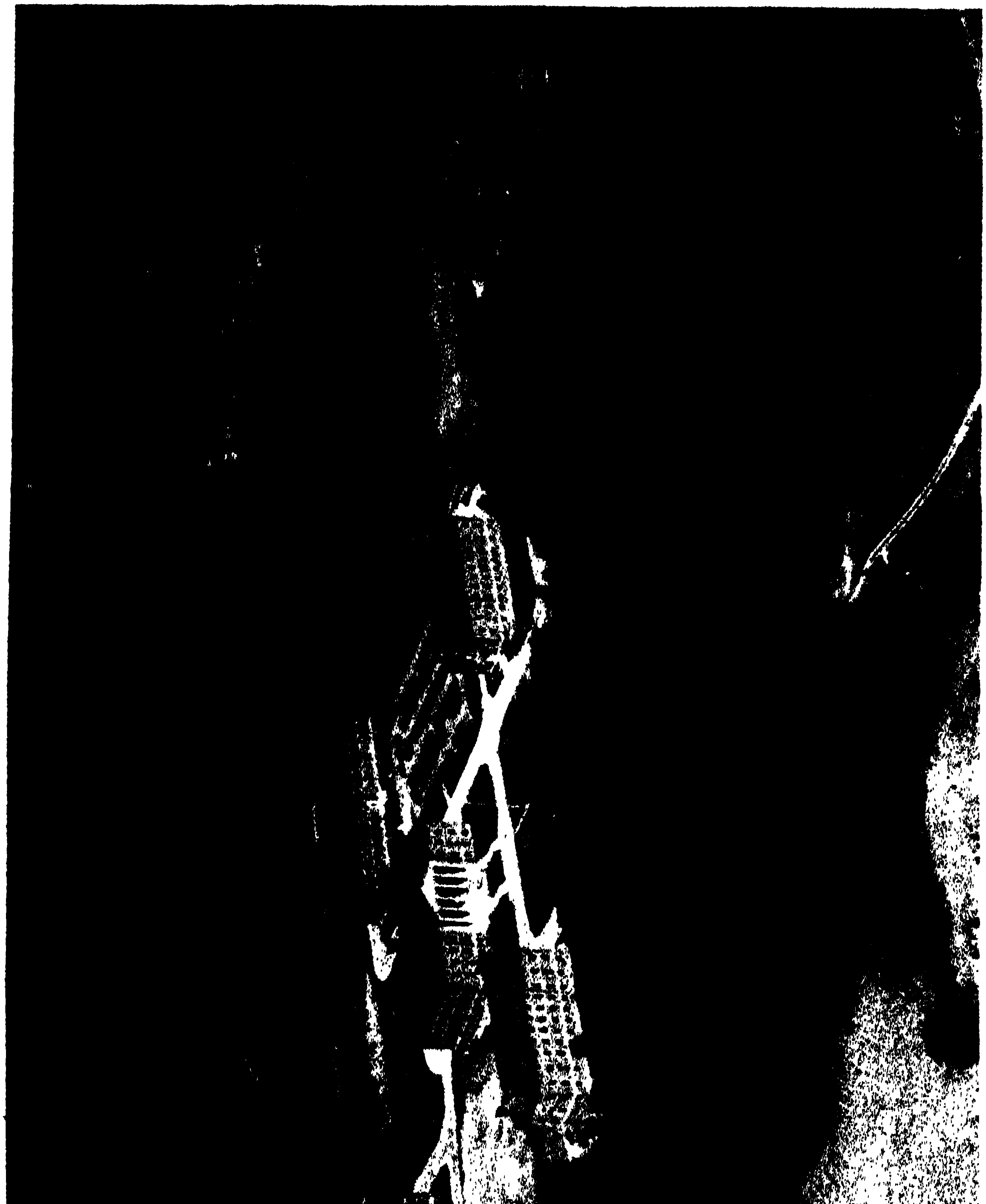
The National Institute of Health in reality is the research division of the United States Public Health Service. On a bronze plaque in the rotunda of the Administration Building of the new institute at Bethesda, Maryland, there are inscribed these words: "This Institute is dedicated to the investigation of matters pertaining to the public health." That brief statement expresses very well the field of activity of the institute.

The institute came into being in a room at the old Marine Hospital at Stapleton, Staten Island, New York, in 1887. Its creation for study of infectious diseases was an example of the wisdom of those officers of the Public Health Service who foresaw that the development of public health work in the United States must be allied with research into these fields. A few years later the institute was transferred to Washington, D. C., and in 1901, with a very modest appropriation of $35,000, the Hygienic Laboratory, as it was then called, came into being on a small plot of ground transferred from the Navy Department. Additional buildings were added in 1918, and again in 1930, at which time the name of the laboratory was changed to the National Institute of Health. In 1935 Mr. and Mrs. Luke I. Wilson donated a tract of land of 45 acres at Bethesda, Maryland, to be used as a site for the National Institute of Health. Then followed in rapid succession the construction of the buildings to house the field and administrative offices of the institute, the Divisions of Industrial Hygiene and Public Health Methods, the National Cancer Institute, and finally the last two buildings of this group of six to house the Divisions of Infectious Diseases, Biologic Control, Zoology, Chemotherapy and Pathology, which were dedicated by the President of the United States on October 31, 1940. As the original site was too small, Mrs. Wilson and her son, after the death of her husband, donated an additional 40 acres.

Although there was never any doubt



THE ADMINISTRATION BUILDING OF THE NATIONAL INSTITUTE OF HEALTH
COMPLETED LAST FALL, THIS BUILDING HOUSES THE LIBRARY AND AUDITORIUM AS WELL AS THE ADMINISTRATION OFFICES.



AERIAL VIEW OF THE BUILDINGS OF THE NATIONAL INSTITUTE OF HEALTH AT BETHESDA, MARYLAND

THE BUILDING WITH THE PORTICO IS THE ADMINISTRATION BUILDING. THE TWO BUILDINGS IN FRONT OF IT HOUSE THE DIVISIONS OF INDUSTRIAL HYGIENE AND PUBLIC HEALTH METHODS. THE TWO BUILDINGS BEHIND IT WILL CONTAIN THE DIVISIONS OF INFECTIOUS DISEASES, BIOLOGIC CONTROL, ZOOLOGY, CHEMOTHERAPY AND PATHOLOGY. THE NATIONAL CANCER INSTITUTE CAN BE SEEN AT THE EXTREME RIGHT.

of the necessity and legal authority for the research work carried on at the institute, it was not until 1912 that Congress enacted into law the broad authority for public health research under which the work of the institute is still carried on. This act, which changed the name of the Public Health and Marine Hospital Service to the Public Health Service, also carried with it authority "to study and investigate the diseases of man and conditions influencing the propagation and spread thereof." Since an appropriation for "Field Investigations" was obtained under the authority of this act, we may take it as the first recognition by the Federal Government of its obligation for the conduct of public health research. Three other acts have had an important bearing on the scope and character of the research work of the institute; these are: the Biologics Act of 1902, which imposed upon the service the control of all biological and analogous products sold in the United States; the National Institute of Health Act of 1930, authorizing the institute to accept gifts for study, research and investigation into the fundamental problems of the diseases of man and matters pertaining thereto; and the National Cancer Institute Act of 1938.

Originally the institute consisted of four divisions—bacteriology and pathology, zoology, pharmacology and chemistry, and was a part of the Scientific Research Division of the Public Health Service. There existed at this time, in addition to the institute, over 20 field offices having to do with certain field investigations such as malaria, stream pollution, child hygiene, statistics, industrial hygiene, nutrition, and others. In 1937 Surgeon General Parran consolidated the Research Division with the National Institute of Health and by the establishment of additional divisions of the institute brought together all the field investigations' offices under one directing head.

The National Institute of Health therefore consists of nine divisions, which are as follows: Industrial Hygiene, Public Health Methods, Zoology, Pathology, Infectious Diseases, Biologics Control, Chemistry, Chemotherapy, and the National Cancer Institute.

The scope of public health investigations undertaken at the institute, while indicated in general by the names of the divisions, reaches down into broad ramifications of health and sanitation problems affecting the people of this country. Some few of these problems may be briefly sketched.

Year by year the population of this country is piling up more people in the older age groups. This means that more of our population are coming into the cancer age and this disease is now second in the important causes of death. The National Cancer Institute is attacking this problem from every angle; it is coordinating and stimulating cancer research in its own laboratories, as well as in other laboratories throughout the nation that are engaged in similar work; it is aiding in the development of cancer control programs in State and local communities; it is cooperating with other agencies in bringing to the people the simple understandable facts about the treatment of cancer; it is training scores of physicians in cancer treatment that these men may be more useful to the people of their communities; it has loaned radium to many hospitals throughout the nation where it is used without cost to those needing treatment, but unable to pay for it; and lastly it has made many grants-in-aid of money to universities and laboratories which need financial assistance in their research problems.

Many health problems have been and are being solved in the Division of Infectious Diseases: Goldberger's work on pellagra; Francis' discovery of tularemia; Spencer's Rocky Mountain spotted fever vaccine; Armstrong's work on poliomyelitis and the other virus diseases, and the contributions of

Dyer and his associates in the rickettsial diseases have given us insight into the prevention and control of many diseases.

In the Division of Industrial Hygiene, not only has this division added much to our knowledge of the prevention of silicosis in the dusty trades, but in a practical way it has aided in the establishment of over 25 industrial hygiene units in the separate states, which in the present expansion of industry in the defense program makes it possible in this country for the first time to control industrial hazards before they exist.

The stream pollution studies of the Division of Public Health Methods have been carried on uninterrupted since 1913. Besides the many contributions to our knowledge of the basic principles of stream purification made by Frost and his associates, the publications of this laboratory have been accepted by our courts of law in the regulation of stream flow in certain sanitary district areas.

From these few illustrations it will be seen that the work of the National Institute of Health in attacking the public health problems of the nation is roughly along two lines: through field and laboratory research we are reaching more deeply into the basic causes of disease and of health, and with this knowledge in our hands we are attempting to apply it to the practical welfare of the people.

LEWIS R. THOMPSON,
Director, National Institute of Health

THE WASHINGTON EXHIBIT OF THE BUREAU OF PLANT INDUSTRY

A DISPLAY covering some of the highlights of the work of the Bureau of Plant Industry was held in the patio of the Administration Building of the Department of Agriculture throughout the month of November. As it was impossible to cover the work of the entire bureau in the space available, attention was focused on investigations concerned with soils and plant nutrition, plant introduction, plant breeding and plant research of special interest to urban residents.

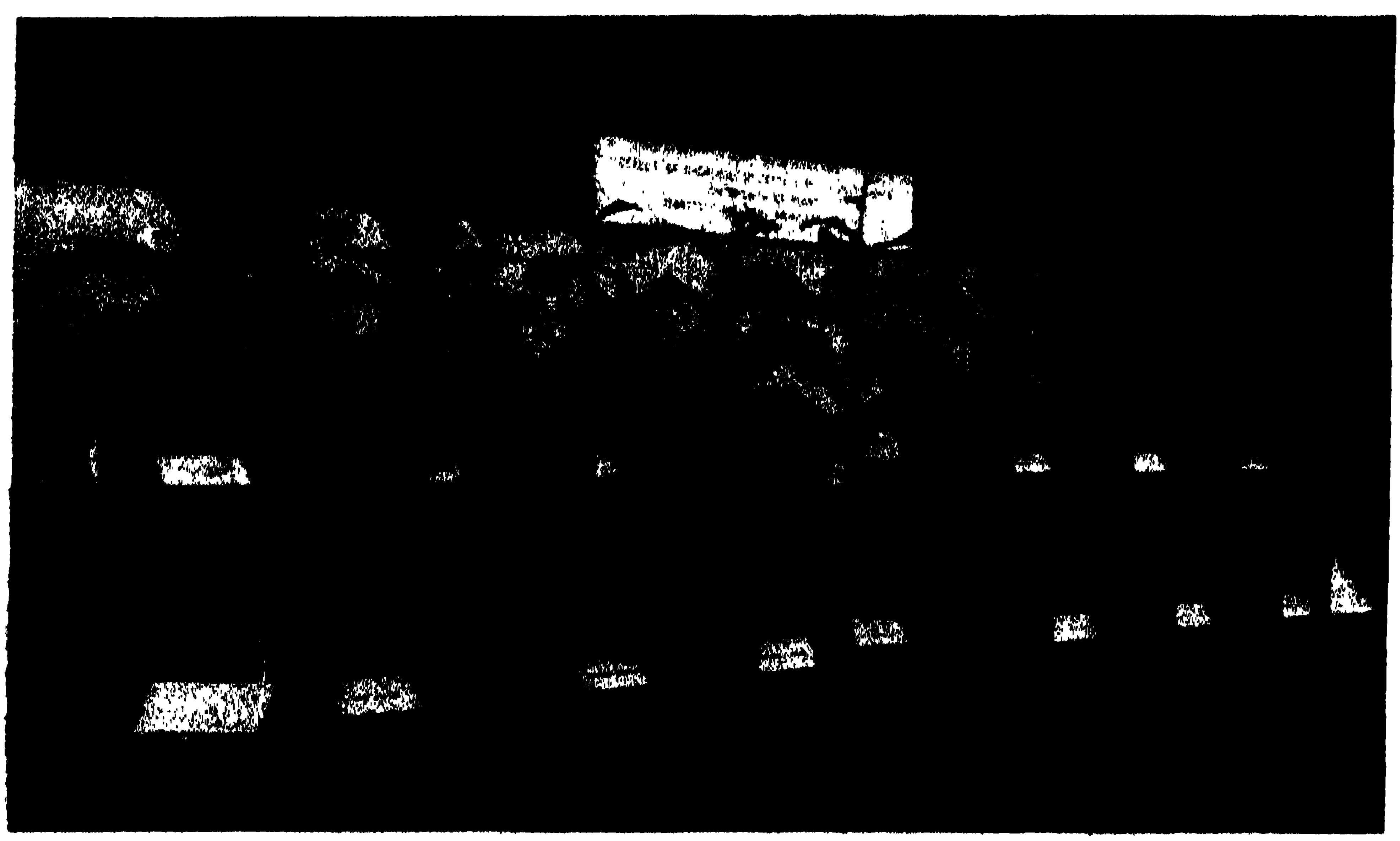
Living plants were used almost exclusively in the exhibits on plant nutrition, introduction, and breeding. This feature attracted unusual interest and lent an air of reality so often lacking in displays that rely on charts and photographs. Each individual exhibit and each of the four groups was planned to tell a story of research achievement. The presence of living plants made it possible to reduce to a minimum the need for explanatory placards. For students and others interested in more detailed discussion, brief mimeographed notes were available.

In planning the exhibit the interests of city dwellers were kept in mind. For this reason one of the features was an exhibit on lawns. At the entrance of the patio a beautiful bluegrass lawn 6 feet square showed results of fall seeding and proper fertilizing. Nearby were four smaller squares of sod each of which had been the victim of poor management. Hundreds of visitors viewed this exhibit and compared notes on their difficulties with lawns.

In the first half of the month chrysanthemums introduced by the bureau were displayed around the fountain in the center of the patio. For the last two weeks this place of honor was occupied by Easter lilies in bloom, forced from American-grown bulbs. In each instance the flowers represented plant breeding work of the bureau.

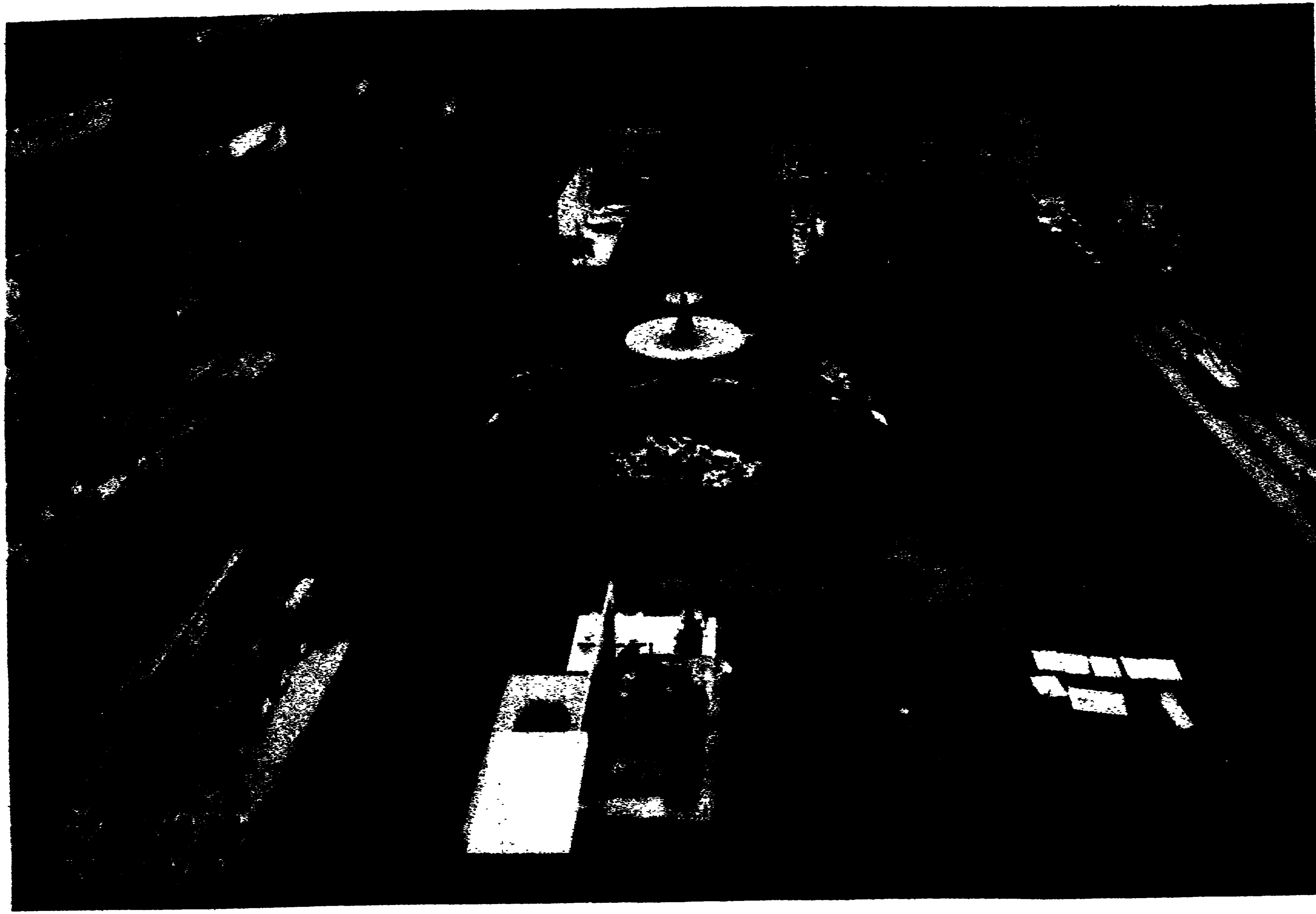
The soils exhibit was built around an enlarged copy of the soil map of the United States. Five-foot monoliths of eight representative soil groups of the country gave many visitors their first opportunity to see what lies beneath the top layer of soil. Equipment used by

CLAUDE R. WICKARD, SECRETARY OF AGRICULTURE, AND DR. M. A. McCALL,
ASSISTANT CHIEF OF THE BUREAU OF PLANT INDUSTRY, EXAMINING THE TOMATO SECTION OF THE EXHIBIT OF THE BUREAU OF PLANT INDUSTRY.



PLANT NUTRITION EXHIBIT

THE TOBACCO PLANT IN THE CENTER WAS GIVEN ALL SOIL CONSTITUENTS NECESSARY FOR ITS FULL DEVELOPMENT. EACH OF THE STUNTED PLANTS ON EITHER SIDE DID NOT RECEIVE ONE OF THE REQUIRED MINERALS.



GENERAL VIEW OF THE EXHIBIT OF THE BUREAU OF PLANT INDUSTRY

IN THE LEFT FOREGROUND IS THE EXHIBIT OF POTATOES, NUTS AND GRASSES; IN THE CENTER FOREGROUND IS EQUIPMENT USED IN MAKING MACARONI, EMPLOYED BY THE BUREAU IN TESTING THE VALUE OF VARIOUS WHEATS AS MACARONI INGREDIENTS. ALONG THE FURTHER WALLS ARE THE EXHIBITS OF PLANT INTRODUCTION AND OF SOIL AND PLANT NUTRITION.

soil surveyors was on display and a series of photographs told how this work is performed.

An exhibit that attracted much attention was a series of 11 tobacco plants growing in glass jars containing nutrient solutions. The center plant had received all the elements necessary for normal development, and stood about five feet tall. On either side were five other plants of the same age. Each had been deprived of one of the elements necessary for normal growth. On a nearby table was an exhibit of fertilizer materials commonly used to provide these elements.

To further emphasize the relationship between soils and plants an exhibit on soil microörganisms was used. The feature of this part of the exhibit was a group of microscopes on which were mounted living nematodes. Slides were replaced every few days so that visitors could see the nematodes moving about under a low power lens.

Although nearly every fruit, vegetable, cereal and nut may seem good American crops, many of them like our people have come from other lands. Two world maps, by a series of symbols, showed that nearly every country of the globe has made some contribution to our foodstuffs or our flower gardens.

NEW VARIETIES OF CHRYSANTHEMUMS
ORIGINATED AS PART OF THE WORK OF THE BUREAU OF PLANT INDUSTRY.

Various tropical and subtropical exhibits included coconuts, once from Malaya, now from Florida; persimmons, once from China, now from California, Texas and other states; pistachio nuts, once from Asia Minor, now from the Pacific Coast, and so the list might be continued almost indefinitely.

As one walked through this portion of the show, looking at the murals of bamboo, rice, persimmons, dates, wild tomatoes, rubber, navel oranges, coconuts; noting the various palms from

Central and South America, the cacti from Argentina, haws from China, almonds from Spain; and studying the seed collections, one could only marvel at the diversity and value of the crops which have been "naturalized" here as a result of plant introduction efforts both public and private.

Except for tree fruits and nuts, all the plant-breeding exhibits consisted of living plants. Crops represented were apples, alfalfa, clovers, grass, cotton, corn, oats, sorghum, wheat, tobacco, tomatoes, sugarcane, sugarbeets and nuts. In most instances the plants were grown in greenhouses especially for the exhibit. Several stalks of cotton with open bolls were sent up from Mississippi and a group of dry-land grasses including Buffalo grass was sent from the Southern Great Plains station at Woodward, Oklahoma.

The aim was to show results, rather than techniques of plant breeding. This was portrayed in a striking manner in the tomato exhibit. This exhibit illustrated how plant diseases are often controlled by breeding. In this case the objective was resistance to wilt. The exhibit consisted of 6 mature plants, all of which had red, ripe fruit, and 12 seedlings, about the right age for transplanting. First in the line-up of mature plants was the wild Peruvian currant, resistant to wilt and collected in Peru by a plant explorer several years ago. Its fruit was about the size of a marble. Next was a typical plant of the Marglobe, introduced by the bureau several years ago and now the leading commercial variety in the country. The third plant was a first generation cross of the first two. The remaining plants were successive backcrosses to the Marglobe parent, and each showed a marked increase in size of fruit. The final product had fruit as large and attractive as that of the Marglobe, and resistant to wilt.

The young plants demonstrated the effect of wilt on Bonny Best, a popular commercial variety, Marglobe, Peruvian currant and the new hybrid. Bonny Best plants were completely killed and Marglobe was badly stunted. The currant and its offspring showed no effects from inoculation with the fungus.

Photographs enlarged to 60 by 80 inches served the double purpose of "walling in" the patio and providing an attractive background for the individual exhibits. In so far as it was possible to get suitable negatives, the photographs were on the same subjects as the exhibits directly in front.

Special invitations were sent to science classes of all nearby high schools and colleges. No actual count of visitors was attempted, but from the number who registered it seems safe to say that at least 3,000 students alone visited the exhibit, in addition to many thousand others. Most of the students came with their teachers and took notes on what they saw.

The exhibit was arranged by a special committee, consisting of one member from each division of the bureau.

E. C. AUCHTER,
Chief, Bureau of Plant Industry
U. S. Department of Agriculture

THE SCIENTIFIC MONTHLY

FEBRUARY, 1941

ASPECTS OF TWIN RESEARCH

By Dr. H. H. NEWMAN[1]
PROFESSOR OF ZOOLOGY, UNIVERSITY OF CHICAGO

BEGINNINGS OF TWIN RESEARCH

SINCE time immemorial twins have been objects of intense interest. Human attitudes toward twins have been greatly influenced by changes in the social evolution of mankind.

Because twins and multiple births are rather unusual they were at first regarded as in some way abnormal and omens of good or evil to the families or tribes into which they were born. Even to-day some primitive tribes treat twins as either objects of awe and respect or as visitations of evil spirits, to be gotten rid of as soon as possible.

Gradually superstitious attitudes toward multiple human births have given way to scientific curiosity about them, but it was a long time before twins and multiple births became the objects of scientific study.

Prior to the twentieth century chief interest in twins was centered on the problem of the nature and origin of double monsters. A long controversy raged over this problem, in which many of the leading biologists of the eighteenth and nineteenth centuries took part. One school of thought upheld the preformation view, according to which double monsters were preformed in the egg or sperm; while their opponents, the epigenesists, believed that doubling was the result of something that occurred during the course of development. Even to-day some biologists hold that double monsters are the products of the fusion of originally separate embyros, while others regard them as the products of the incomplete fission of an originally single embyro.

It was not until 1904 that double monsters came to be regarded as instances of incomplete one-egg twinning, when H. H. Wilder elaborated this view in his significant paper, "Duplicate Twins and Double Monsters." Wilder showed that separate one-egg twins and symmetrical double monsters, for which he invented the term "cosmobia" belong to the same series. Wilder seems to have been the first worker to make detailed comparisons between the members of one-egg twin pairs and to carry this comparison to such minutiae as finger prints and palm prints.

So far as we have been able to ascertain, the first to recognize the existence of two kinds of twins, one-egg and two-egg twins, was Sir Francis Galton. By a stroke of genius he guessed that these two types of twins exist and leaped to the logical conclusion that one-egg twins were genetically alike and that two-egg twins were merely siblings conceived and born together. Galton promptly realized the use to which twins could be put as materials for genetic research.

By the use of questionnaires sent out to a considerable number of twins of

[1] Dr. Newman is author of *Multiple Human Births*, the first of the American Association for the Advancement of Science series of non-technical books on important scientific subjects of wide general interest.

STRIKINGLY SIMILAR "IDENTICAL" TWINS

SEPARATED AT EIGHT DAYS OF AGE AND REARED IN QUITE DIFFERENT ENVIRONMENTS. IN THE UNITED STATES ABOUT ONE BIRTH IN 88 CONSISTS OF TWINS, OF WHOM ABOUT ONE FOURTH ARE ONE-EGG (IDENTICAL) TWINS AND THREE FOURTHS ARE TWO-EGG TWINS.

both types he sought answers to two main questions:

(1) Do fraternal (two-egg) twins grow more similar as the result of being subjected for years to a common environment?

(2) Do identical (one-egg) twins grow more different after being separated and living under different environmental conditions?

The questionnaires seemed to give negative answers to both questions. Fraternal twins, instead of growing more similar as the result of living together for years, persisted in exhibiting marked differences and often became increasingly unlike; while identical twins, even when one had lived for years in India and the other had stayed in England, remained as similar as ever.

On the basis of these results Galton came to the conclusion that environmental differences, such as are to be found in the same community and at the same time, produce only slight changes in the individual's physical and mental traits,

which are, therefore, determined chiefly by "inborn nature." These first studies by Galton were published in a paper entitled, "The History of Twins as a Criterion of the Relative Powers of Nature and Nurture." Thus began the scientific study of twins.

Twin research between 1876, the date of Galton's publication, and 1904, when Wilder aroused new interest in twinning problems, was largely limited to statistical studies.

As early as 1885 Veit had made an extensive study of the frequency of twin, triplet and quadruplet births in Germany and had determined for that country that on the average there occurred one twin birth in 85 births. Ten years later Hellin announced his remarkable rule, called "Hellin's Law." This rule is that if the frequency of twins to total births is 1 to 85, the frequency of triplets is 1 to 85^2, while that of quadruplets is 1 to 85^3. This rule agrees remarkably closely with actual mass data. Just why, nobody knows.

In 1902 Weinberg, on the basis of the sex distribution of very large numbers of twins, came to the conclusion that not only are one-egg twins a reality, but that about one fourth of all twins are one-egg twins. Weinberg reasoned that there should be equal numbers of same-sexed and opposite-sexed two-egg twins. By doubling the number of boy-girl twin pairs (surely two-egg twins), making an allowance for the slightly greater number of males than females, and subtracting this number from the total number of twin pairs in a country, he obtained the number of one-egg pairs. This came to be known as the Weinberg Differential Method. In 1907 Nichols used the Weinberg method in determining the percentage of one-egg twins to all twins in the United States to be about 26. This was in close agreement with Weinberg's figure for Germany.

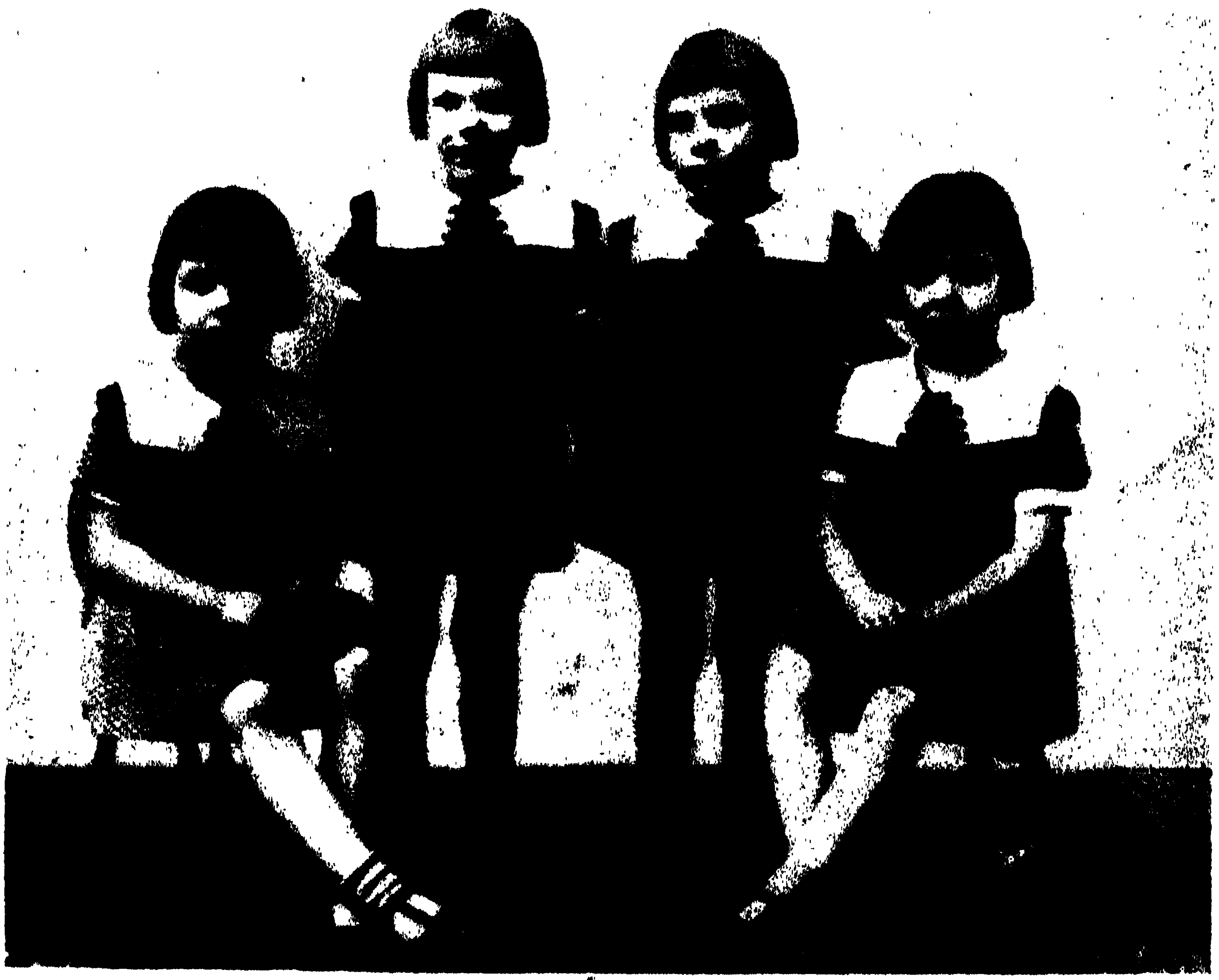
Up to the time when Weinberg showed statistically that a large number of same-sexed pairs of human twins must be one-egg twins the existence of such twins was

CLOSELY SIMILAR "IDENTICAL" TWINS

ALTHOUGH THE ONE ON THE LEFT WAS REARED IN LONDON AND THE OTHER IN A SMALL TOWN IN ONTARIO, CANADA, THEIR RESEMBLANCE IS UNMISTAKABLE. (JOURNAL OF HEREDITY.)

purely hypothetical. Galton, on the basis of the very strong intra-pair resemblance in so-called "identical twins" had reasoned that such twins must have a common genetic make-up and therefore must have been derived from a single egg. At that time there was no direct embryological evidence that one-egg twinning ever takes place among mammals.

The first reports on these two studies were both published in 1909. In both these species of armadillo but one egg is involved in each pregnancy, as is evidenced by a single corpus luteum. All fetuses in a set are of the same sex. In the Texas nine-banded armadillo (*D. novemcinctus*) four fetuses are arranged very regularly within a single chorion,



IDENTICAL ONE-EGG QUADRUPLETS

ONLY ONE BIRTH IN 600,000 CONSISTS OF QUADRUPLETS; A FRACTION OF THEM ARE OF ONE-EGG ORIGIN.

The Turning Point

So long as the actual existence of one-egg twins remained hypothetical, little use could be made of twins in the investigation of human problems. One crucial step in the direction of laying a secure foundation for twin research was the discovery and study of one-egg twinning in two species of armadillo, *Dasypus novemcinctus* (Newman and Patterson) and *Dasypus hybridus* (Fernandez).

two on one side and two on the other. In the South American species (*D. hybridus*) from seven to twelve embryos are derived from a single egg. In succeeding years Newman and Patterson studied and reported on the complete embryonic history, showing conclusively that the embryo up to a fairly advanced stage develops as a single individual and then undergoes two twinning divisions. The first division gives rise to symmetri-

FILIPINO "SIAMESE" TWIN BOYS AND THEIR "IDENTICAL" TWIN WIVES

cally placed twin primordia, each of which divides evenly again to form a secondary pair.

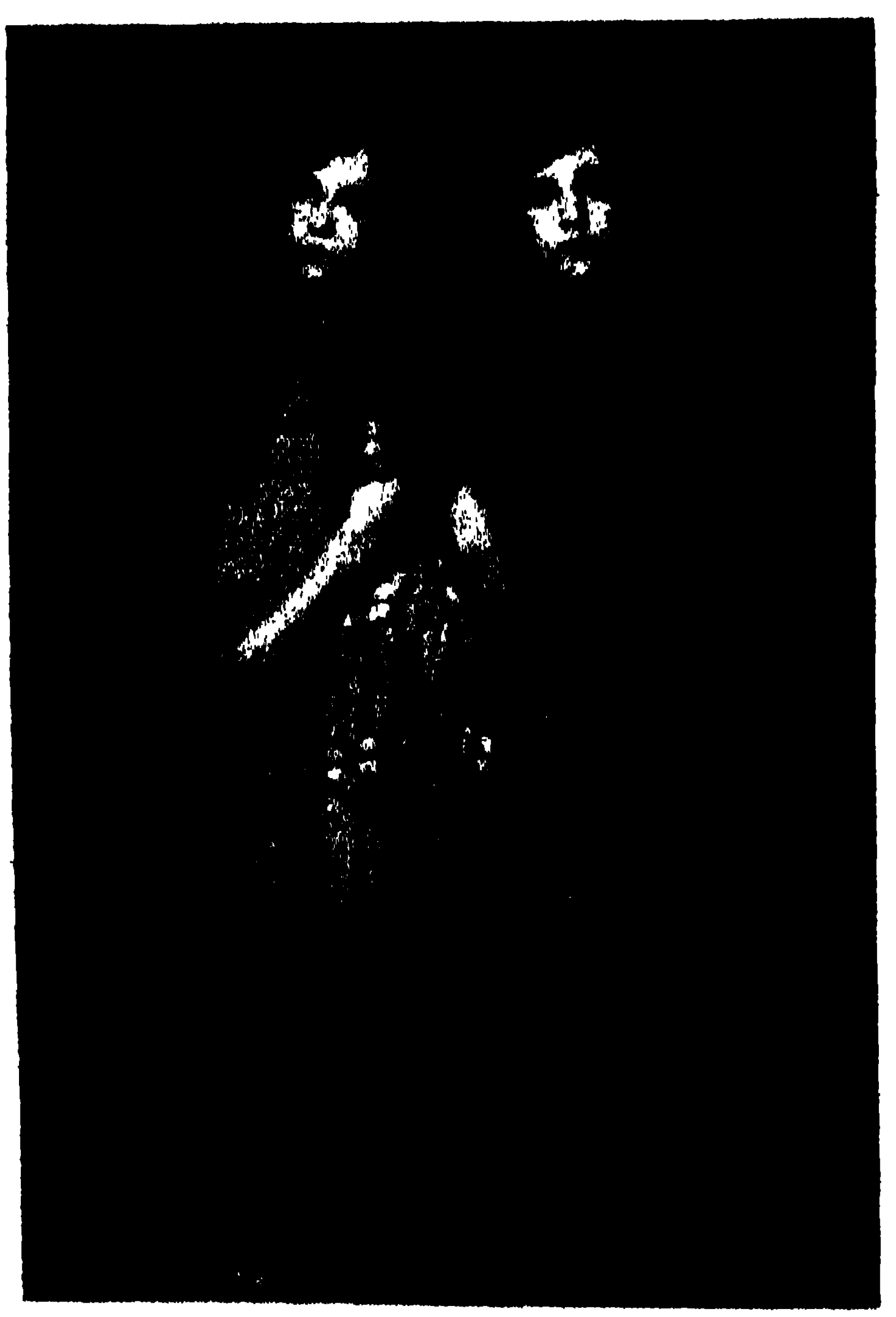
Newman made a statistical study of the degrees of resemblance and difference with respect to numbers of scutes in the

armor and found that the intra-set coefficient of correlation for the banded region was about .92, while that between members of secondary pairs was somewhat higher, about .935. These correlations were of the same order as those previously determined for right and left sides of single organisms.

Newman also showed that rare band irregularities in the armor (regionally doubled bands) were inherited, and in a very peculiar way. If the mother has a partly doubled band near the left margin of Band 1, fetus 1 may have a similar character on the left side, fetus 2 on the right side, fetus 3 on both sides and fetus 4 on neither side. Thus four individuals genetically alike may express an inherited character in several different ways, or even not at all. There is thus a distinct contrast between inheriting and expressing a character. There was also noted a considerable amount of mirror imaging between individuals of the same set of young armadillos.

THE HAND OF MARIE DIONNE

It was only natural to suspect that, since one-egg twinning takes place so regularly in certain mammals, it probably takes place sporadically in much the same fashion in human embryos. It has not been possible, for obvious reasons, to study the early stages of one-egg twinning in man; so for the present and until we secure evidences to the contrary, we must take the twinning picture revealed by the armadillos as the best model for human one-egg twinning.



THE HILTON "SIAMESE" TWIN GIRLS

It was with this idea in mind that in 1917 I wrote a little book, "The Biology of Twins," in which I described the course of twinning in various armadillos, dealt with the extent to which variation occurs among individuals alike genetically, and then reviewed our knowledge of twinning, both one-egg and two-egg, in other mammals, including man. This little book, according to leading twin specialists in various parts of the world, served the purpose of focusing their attention upon human twins and their

possible uses as materials for research. From this small beginning has grown a new and thriving branch of biological research engaging the attention of many investigators in a dozen different countries and in a score of different fields of scientific inquiry. In 1923 I published a second book, "The Physiology of Twinning," in which were brought together for the first time all previously published data on one-egg twinning in the animal kingdom. In this book I discussed the causes and consequences of one-egg twinning and suggested the uses to which twins could be put in further research problems. Some of the theories of twinning proposed at that time excited considerable controversy and stimulated additional research.

"IDENTICAL" TRIPLETS
ONLY ABOUT ONE BIRTH IN 8,000 CONSISTS OF TRIPLETS, ONLY A FEW OF WHOM SURVIVE THE HAZARDS OF MULTIPLE BIRTH AND ONLY A PART OF WHOM ARE DERIVED FROM ONE EGG.

The Modern Period

Arbitrarily, I would be inclined to set the date of the beginning of the modern period of twin research at about 1924. Certainly the vast majority of publications in this field have appeared since that date. About that time extensive programs of work on a great variety of twin problems were begun in several countries, the chief of which were the United States, England, Germany, Austria, Japan, Norway, Sweden, Denmark, Holland, Russia and Finland.

Modern twin research may be conveniently divided into two main categories: *a*, studies of the various aspects of twins and multiple births that contribute to our knowledge of the nature, causes and frequencies of twins, etc., and *b*, studies in which twins are used as materials for the investigation of problems in a multiplicity of other fields.

Among the investigations dealing with twins themselves are the following:

(1) Studies of the relative frequencies of twins of the two main kinds among different races and under different environmental conditions.

(2) Studies of the varying proportions of one-egg and two-egg twins in various populations.

(3) Studies of methods of experimental induction of twins in lower animals.

(4) Detailed studies of multiple births, such as quadruplets and quintuplets.

(5) Methods of distinguishing between one-egg and two-egg twins. The same

methods are also applied to multiple births.

(6) Analysis of reversed asymmetry, or mirror imaging, in twins and its significance.

(7) Studies of resemblances and differences in one-egg twins, triplets, quadruplets, and quintuplets, especially of the Dionne quintuplets.

(8) Studies of mutual intimacy and social interrelations of twins.

DEMONSTRATION OF HEREDITY
IDENTICAL TWIN SISTERS AND THEIR IDENTICAL TWIN NEPHEWS.

(9) Investigations of the prenatal and birth hazards of twins and their relatively high infantile death-rate.

(10) The reasons for the higher prenatal death-rate of one-egg than two-egg twins.

(11) Studies of the dermatoglyphics (palm, finger and sole prints) of twins and multiple sets.

(12) Studies of the inheritance of the twinning tendency.

(13) Special studies of conjoined twins, especially dealing with mirror imaging and differences between the two components.

(14) Studies of the relatively high frequency of one-egg twins in tubal pregnancies.

Among the applied aspects of twin research are those numerous studies in which twins are used to throw light on various problems in fields remote from that of twinning as such. Taking as a starting point the fact that one-egg twins are identical genetically and two-egg twins differ to the same extent as siblings, it is possible to determine by appropriate methods the extent to which various human traits are hereditary and the extent to which such hereditary traits are or may be modified by differences in environment and training.

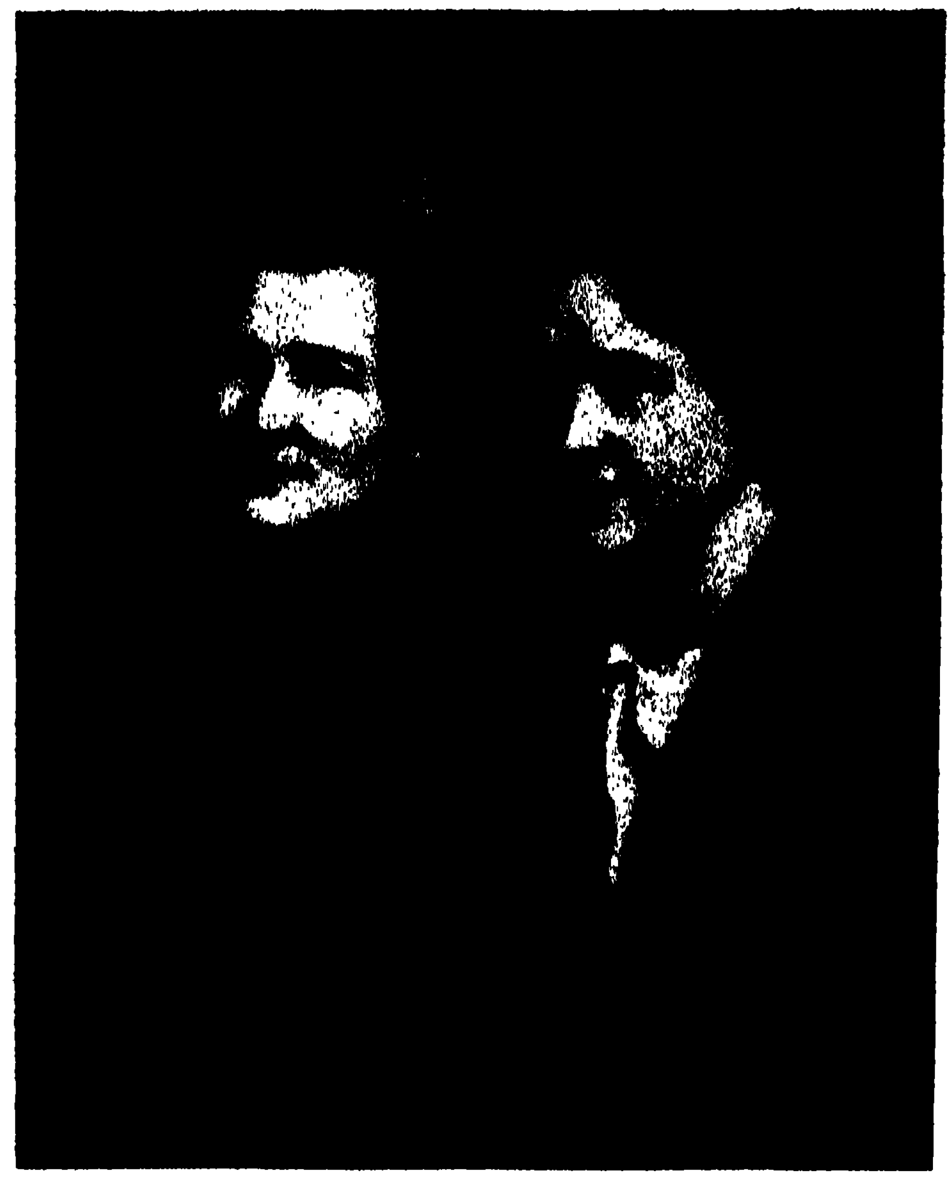
Three main methods have been used in these studies: *a*, the concordance-discordance method; *b*, the co-twin control method; and *c*, statistical methods.

The Concordance-Discordance Method

H. W. Siemens, a Dutch dermatologist, seems to deserve credit for the first attempt to use twins in the scientific study of pathology. In 1924 he published his book, "Die Zwillings Pathologie," in which he presented his investigations of dermatological anomalies and diseases in numerous pairs of twins and a few sets of triplets. He also is the first to have published a method of distinguishing between one-egg and two-egg twins, a method now called the "similarity method" and adopted in various modified forms by all students of twins. Siemens may be regarded as perhaps the pioneer of modern applied twin research.

The underlying concept of Siemens was that all anomalies and diseases that were always present in both members of a pair of one-egg twins and only rarely so in two-egg twins, were fully hereditary; that when such conditions were not always present in both of one-egg twins,

but more frequently so than in two-egg twins, these are partly hereditary but due partly to differences in environment. Cases of complete correspondence in both members of a pair were termed concordant (+ +), cases of differences in degree of correspondence were designated (+[+]) and total lack of correspondence was called discordance (+ −). Siemens' methods have been extensively used in many types of study, notably those on criminality, psychiatry, ophthalmology, genetics of anomalies and diseases, etc. Such studies are too numerous to review in this brief historical sketch. Suffice it to say that through the use of this method our knowledge of the genetic basis of a large number of human characters has been discovered or confirmed, that many problems in human physiology and behavior have been illuminated, that new knowledge as to hereditary dif-



GLADYS AND HELEN
SEPARATED AT EIGHTEEN MONTHS TO MEET AGAIN AT AGE TWENTY-EIGHT, WERE REUNITED AT THE CHICAGO EXPOSITION IN 1933. THEY VISITED THE GROUNDS IN COMPANY WITH EDWIN AND FRED, TWO "IDENTICAL" TWIN YOUNG MEN, THE FOUR AROUSING MUCH INTEREST AT THE FAIR.

KENNETH AND JERRY, ONE-EGG TWINS
BROUGHT TOGETHER BECAUSE A TEACHER VISITING ANOTHER TEACHER IN A DISTANT CITY NOTICED A BOY IN ONE OF THE CLASSES WHO STRIKINGLY RESEMBLED A BOY IN HER OWN SCHOOL.

ferences in susceptibility to contagious diseases has been obtained, that differences in sleeping and waking habits have proven to be largely hereditary, that criminalistic tendencies have been shown in many cases to have a definite hereditary basis, and that various well-known types of psychoses and neuroses are also hereditary.

The Co-twin Control Method

In these studies one-egg twins must be used exclusively; otherwise the control aspect of the study is wanting. Assuming that a pair of one-egg twins is genetically identical, one member can be used as a control and the other subjected to experimental treatment. Arnold Gesell, Yale child psychologist, seems to have been the first to use this method in the study of the effects of training in young infants. As the result of the detailed study of one pair of one-egg twin babies,

he concluded that the training of one twin at a later period for a shorter time was as effective as training the other twin at an earlier period for a much longer time, and hence that much of the improvement of skills was the result of pure maturation of the nervous system, which becomes more efficient merely as the result of development.

One other alleged co-twin control experiment has been extensively publicized, namely, the case of Myrtle McGraw's Johnnie and Jimmie. This would have been a highly significant experiment had not the twins turned out to be of the fraternal (two-egg) variety and thus lacking all elements of co-twin control.

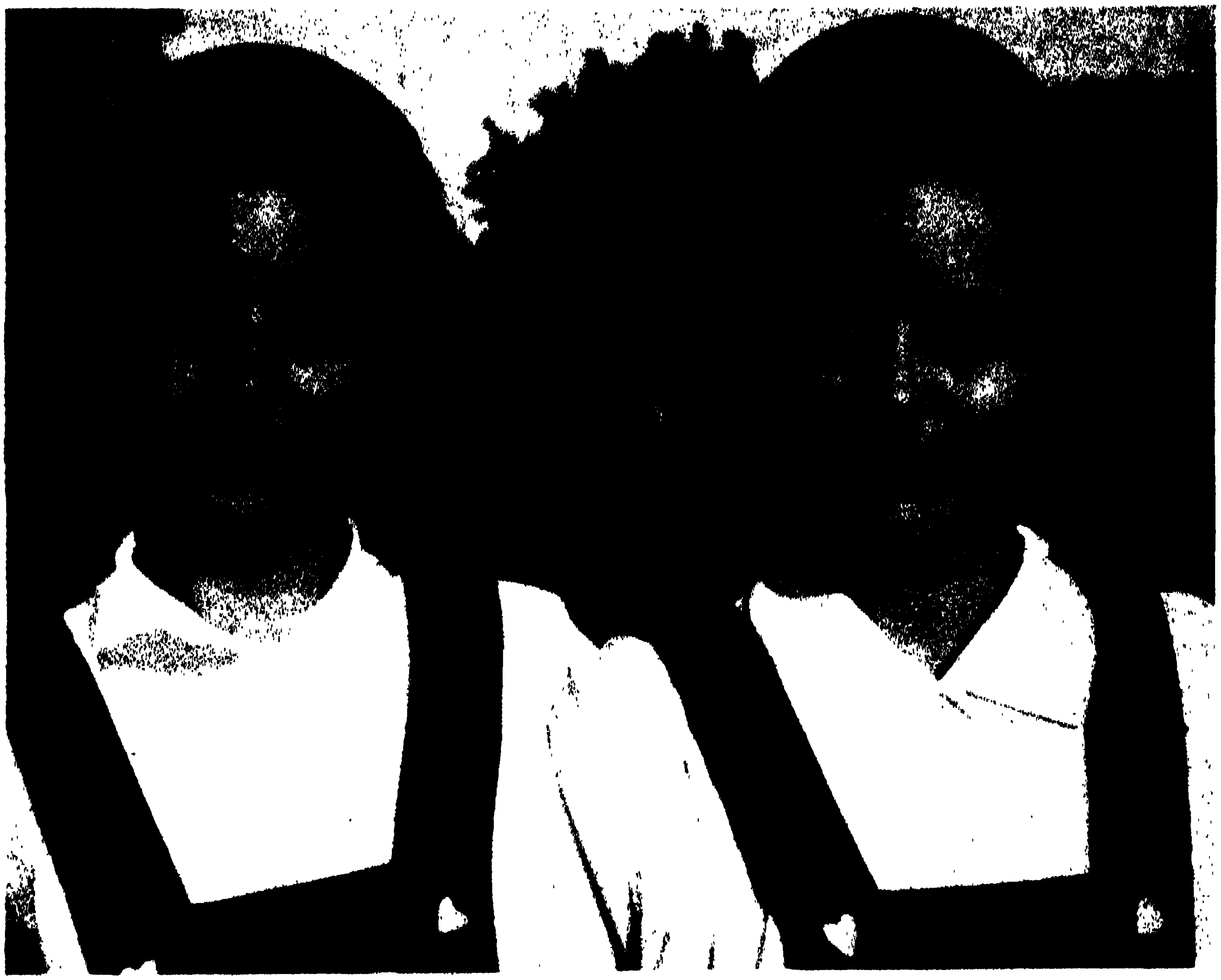
Much more extensive use of the co-twin control method was made in Russia. A group of scientists at the Maxim Gorky Medico-genetical Institute of Moscow, as part of an extensive twin research program, maintained a dormitory for a number of pairs of preschool-age one-egg twins. These were kept in an environment as nearly uniform as that usually maintained in an experimental animal colony. Many kinds of experiments were conducted with this twin colony, involving both physiological and psychological problems. It would be beyond the scope of the present article to report the results obtained and the conclusions reached, but suffice it to say that they were important. Just when this fruitful and highly promising program of twin research was in full flower it was uprooted and abandoned by the governmental authorities. And this, for reasons best left undiscussed. Now that the Russian experiments are, for the time being at least, abandoned, American investigators should by all means enter this field of research, for the method of co-twin control cries out for exploitation.

Statistical Methods

There is not one but many statistical

THE TWO PAUL HEROLDS

EACH YOUNG MAN WAS IGNORANT OF THE OTHER'S EXISTENCE FOR TWENTY-THREE YEARS AND WAS REARED IN ENTIRELY DIFFERENT SURROUNDINGS THAN HIS BROTHER.



THE ATTRACTIVE BAILEY TWINS
ARE AS MUCH ALIKE AS TWO PEAS IN A POD OR AS TWO PEACHES ON A TREE.

methods of employing twins in genetic research. All of them, however, depend upon our ability to distinguish one-egg from two-egg twins. Much attention has been given in recent years to attempts to find accurate, objective methods of diagnosing one-egg twins. In actual practice, experienced students of twins seem to have but little difficulty, if care and a sufficiently large number of characters are employed, in diagnosing twin types.

Once having a sufficiently large group of one-egg twins, these can then be used as a basis for determining the extent to which hereditary characters may vary in expression either under nearly identical environments or under environments differing in all sorts of ways.

A considerable number of studies based upon a comparison of the relative intrapair differences between one-egg and two-egg twins have been conducted by both American and European workers. The pioneer study in this field was made in 1905 by E. L. Thorndike, dean of American educational psychologists, but his work was considerably hurt by his failure to be able to diagnose twins of the two types, and by his decision, which he now knows to be ill-founded, that all twins belong to a continuous series and have a common mode of origin. Following Thorndike's lead, Lauterbach, Merriman, Wingfield and Hirsch all attacked the hereditary-environment problem and approached a more satisfactory analysis of it.

The most recent study in this field is that of Newman, Freeman and Holzinger. This study published in 1937 in book form is in most respects perhaps somewhat more exhaustive than preceding studies and may be taken as an example of this type of twin research. One-egg

ELEANOR AND GEORGIANA

WHO, AFTER TWENTY YEARS' SEPARATION, WERE BROUGHT TOGETHER AS A CONSEQUENCE OF THE FACT THAT A CATHOLIC SISTER WHILE TRAVELING ON A BUS MISTOOK ONE FOR THE OTHER.

twins (50 pairs) are used as a control. For each pair the heredity is the same and the environment as nearly alike as humanly possible without laboratory control. One of course assumes that any differences between one-egg twins must be due to differences in either prenatal or postnatal environment or to both. If now we take an equally large group of same-sexed two-egg twins and find, as we

do, that the intrapair differences are much greater in almost every character than those of one-egg twins, we can calculate the extent to which hereditary factors alone are responsible for differences in two-egg twins. The method developed by my colleague, K. J. Holzinger, is to subtract the intrapair coefficient of correlation of two-egg twins from that of one-egg twins and divide the remainder by 1 minus the intrapair coefficient of correlation of two-egg twins. This gives the percentage share of genetic differences responsible for intrapair variance for one character at a time. The formula used was: $h_2 = \frac{{}_i r - {}_f r}{1 - {}_f r}$, where h_2 is the percentage share of hereditary determination of the observed intrapair difference in two-egg twins, ${}_i r$ the intrapair coefficient correlation of identical (one-egg) pairs and ${}_f r$ that of fraternal (two-egg) twins. Thus for any character measured for both groups of twins the shares of hereditary and environmental factors responsible for observed differences may be determined with a high degree of accuracy, limited only by the accuracy of measurements and tests used.

Another phase of our work was the rather laborious collection of twenty pairs of one-egg twins separated in infancy and reared apart under a great variety of different environmental conditions. In this study it was found that the intrapair differences with respect to nearly all physical characters were no greater than those in one-egg twins reared together, indicating that any significant differences in these characters are probably determined by differences in prenatal environment.

Intrapair differences in mental ability and scholastic achievement were, however, considerably greater in the separated than in unseparated pairs and these differences were definitely corre-

CECILE, MARIE, EMILIE, ANNETTE AND YVONNE DIONNE
AT ABOUT TWO YEARS OF AGE, THE ONLY KNOWN LIVING QUINTUPLETS; THEY ARE "IDENTICAL."

THE BADGER QUADRUPLETS
THE TWO ON THE LEFT HAVING BEEN DERIVED FROM ONE EGG AND EACH OF THE TWO ON THE RIGHT FROM A DIFFERENT EGG. CONSEQUENTLY THE SET WAS DERIVED FROM THREE EGGS.

lated with degrees of difference in education. Temperament-emotional differences were also in many cases quite marked in the separated pairs and could usually be referred to marked differences in environment and experience. The individual case studies of these twenty pairs of separated one-egg twins often revealed the ways in which differences in environment had a moulding effect upon personality traits. It would hardly be appropriate in this general review of twin research to discuss our own contributions at greater length.

The field of twin research is a rapidly expanding one. Already my own private bibliography contains titles of over five hundred publications about twins and multiple births. There are still many unsolved problems and open questions in this field that would well repay further research.

EXPLORATION OF MUMMY CAVES IN THE ALEUTIAN ISLANDS

PART II. FURTHER EXPLORATION

By Dr. ALEŠ HRDLIČKA

CURATOR OF THE DIVISION OF PHYSICAL ANTHROPOLOGY, U. S. NATIONAL MUSEUM, SMITHSONIAN INSTITUTION

AMLIA

FROM the Atka natives we have learned of a "mummy cave" on the long island to the east, Amlia; and on July 4, at 4 A. M., start for the same, with a native guide, former Atka chief, on the *Talapoosa*. By 8 arrive opposite a cove on the northern shore. The "cave" is on the south shore, but the sea is rather rough, barometer unpromising, and Captain unwilling to risk under such conditions dangerous south coast. So dory takes party to the cove we see, and at 9 A. M. we start on a walk across. The native says it is "a 2 hours' walk." Climb over hills, lowlands and along a lake, partly in water, 3¼ hours, before reaching the place. The native knows of the cave only "in general," but has guided us well. On a gravelly isthmus we find a moderate-sized old village site, and to the S. of this among great fallen rocks two skulls. Further on along the cliffs discover two rock shelters, with several more skulls and some bones, also a wooden dish over a skull, remnants of a red kayak and few other objects, but no cave, no mummies. A small platform built rather ingeniously in a rock-cleft above one of the shelters did probably once hold a mummy, but nothing is left of it—the trappers had been here first.

Cold, drizzly; fire in a native little half-underground lean-to nearly chokes at first with smoke, but we manage to make a can of coffee. Explore cliffs and rocks on all sides—no other remains discoverable. Dig a little—2 stone implements.

In the rock shelters get two pieces of fine wood-carving, and some bone implements.

Have to depart at 4—reach north cove 7:15. Dory there waiting—a rough trip to ship—have to climb up on emergency matting—but all ends well. At 9:00 P. M. start westward, for excavations on unknown Agatu, one of the two westernmost Aleutians.

The party on this trip visited Adak, Attu, the Commander Islands, and was then landed and left alone on Agatu, where for three fruitful weeks excavations were carried on in two old sites. But the caves and especially the Ship-rock were not forgotten. On August 8 the party was taken on board the fine new Cutter *Duane*, Captain P. F. Roach, and proceeded eastward. The first stop was to be made at Tanaga.

TANAGA, ILAK

Off the large island of "Tanaga," Makarii, the old chief of Atka and our guide at Amlia, saw "many years ago" a mummy cave or shelter. The information as to the location of the cave was rather indefinite and without any details as to contents, but in the main probably reliable, and so it was decided to look for the hollow. This is how we fared:

Aug. 10, 1937. Fog. At 1 P. M. reach off Tanaga—but at first the wrong bay. Fight fog and current rest of afternoon, without success. Anchor for night somewhere off the coast.

Aug. 11. Higher winds; less fog, but can see only a small part of land on left. Ship rocks more, though not bad. Prospects not good.

9 A. M. Fog thickens again, no land in sight any more. Ship about five miles off shore, but dares not send a boat out in the fog.

10 A. M. A dory sent out to reconnoiter, under protection of ship's sirens —returns in half an hour without having seen anything—could not dare to go further. Captain very nice about it all, will wait.

11 A. M. Fog all around, visibility only about 200 yards in any direction.

12 to 6 P. M. Dory sent out twice— could not prevail, once lost for a time. Fog the same. At 4 sun partly penetrated, but did not show itself full, nor dispelled.

9 P. M. No change.

Aug. 12, 6–7 : 30 A. M. At last sea nearly free from fog. Ship has been riding far out, now returning once more towards land. A cape dimly visible towards the west. Land still in haze, but perceptible. Sea somewhat rough.

9–1 A. M. Have reached near pinnacles and rocks off land, visibility now fairly good. Leave in the dory for a small "black island" somewhat over a mile off. Circle around, find it volcanic, craggy, unboardable even on the lee side, and wholly unpromising—not high enough, and no caves or overhangs where water could not reach them.

Pass on to two small islands in the western end of the "bay," about three miles from the first. The one to right, nearer land, partly grassy, partly craggy, unpropitious. The further one,

THE "GANG" OF VOLUNTEER STUDENTS

ACCOMPANYING THE AUTHOR IN 1937. THE TOOLS OF THIS PARTY ARE THE PICK, THE MATTOCK, THE SHOVEL AND THE WHEELBARROW. THE DRESS CONSISTS OF RAINCOATS AND HATS, WARM UNDER AND OUTER CLOTHING, HIGH BOOTS AND CANVAS GLOVES. LEFT TO RIGHT: WALTER WINEMAN, PAUL GEBHART, PAUL GUGENHEIM, SYDNEY CONNOR, ALAN MAY, STANLEY SEASHORE.

DISEMBARKING OF THE AUTHOR

WHO, NOT HAVING HIS HIP BOOTS, MUST BE CARRIED ASHORE ON THE SHOULDERS OF A SAILOR. THE BOAT AND CREW ARE FROM THE COAST GUARD BOAT WHICH BROUGHT THE PARTY OVER.

volcanic, craggy, about 60 feet high, scaled—getting out of the boat perilous—and examined—no vestige of anything human; and no cave or crevice that could have had any remains.

In distance—about five miles—towards the east or southeast, see a point and off there a rock with two islands—more likely our destination; but sea rather rough, 30 mile wind, must return to ship before attempting to reach these. Come back wet, but without any damage. It is 11 A. M. Ship now moves towards the above islets and endeavors to anchor (43 fathoms) about a mile off—but anchor will not hold, sea is rougher, and so Captain decides to try Ilak first. Have sighted it in haze to the south. The isle has a bad reputation for storms and dangerous rocks; but there was known to be in its cliffs a cave with mummies. Many years ago—Mr. Willis, now of Dutch Harbor, found this cave and saw in it, "sitting around," probably a score of mummies. But, it was learned later, three years ago, the cave had been sacked by a couple of fox trappers, who were known to have brought out a good deal of "loot"—though not the mummies—and who a year after were capsized off the place and drowned.

Reach off Ilak—16 miles from our anchorage at Tanaga. Not easy to locate a landing place for the dory. Find, most unexpectedly in this entire volcanic region, a wholly *granitic* and not volcanic island (whitish stone), with a flat top. Much like one of the southwestern mesas. Perhaps 300 feet high, grassy slopes and foreground (north), a bouldery beach, many shore and off-shore "bad" rocks. On the northwest part see high rough cliffs. A trapper's shack about 100 yards from water near middle of north shore. Bad walking in tall

grass—at times some of the party not visible in the rank vegetation. Along shore must jump like goats over boulders, yet these offer the best way. In parts the granite outcrops stand on edge, offering broken sharp ridges.

Explore everything likely towards northwest, and about a mile from the shack locate a cave, in a high bare rough pinnacle, with a lot of human debris, wood, stones, human bones, parts of four skulls. Digging shows about 2½ feet of debris—soil, stones, more or less decayed wood, grass, traces of matting, stray human and bird bones; underneath more wood, then a good layer of debris of mollusks (limpets), with some bird bones, a few chipped, and one polished, knives, a wooden bowl, no human bones; and lowest down flat fire stones, ashes, debris.

Cave had evidently originally been occupied, then used for a burial place. Not long ago the whole was disturbed, mummies and skulls taken away, bones with remains of wooden utensils scattered or thrown out. Doubtless the reported mummy cave—the driftwood poles and debris indicate that—but now all vandalized by the trappers.

We collect what is worthwhile, and excavate whole accumulation in the not very large space. Subsequently one of my boys (May) discovers another "hole in the rocks," somewhat further westward, with six mossy skulls, some in good condition. And another of the boys, a former Scout (Conner), is sent on a trip around the island—but finds no more man-used caves, or other traces of human remains.

Carry everything saved back over the

OLD SITE OF UMNAK WITH PRESENT ALEUT DWELLING

NOTE THE RACK FOR DRYING FISH AND TWO PARTLY UNDERGROUND CHAMBERS, ONE USED AS THE SWEATBATH AND THE OTHER FOR STORAGE.

HELL'S KITCHEN ON AMLIA ISLAND
AN EXAMPLE OF THE EXCESSIVE EROSION AND ROUGHNESS OF THE COAST IN MANY PARTS OF THESE ISLANDS. AN OLD BURIAL CAVE IS CLOSE BY BUT NOT VISIBLE.

rocks and through the grass, including a heavy movie camera, reaching hut quarter to eight, sweating and wearied; have some hot coffee there, made by boat men who stayed behind, with raisin bread. At dusk depart, at 9:30 back on the ship. Weather better now, wind less, but Captain tired, has gone to sleep, and so ship remains here over night.

Aug. 13. Wind weak, sea fairly good though a swell, horizon misty, but no real fog. Tanaga not visible.

At 9 up—anchor and back to Tanaga.

9:15—wind freshens, fog envelopes top of Ilak. Run slowly.

At 12 anchor off Tanaga again. Rather fairly clear now, sea with smooth heave only.

12:30—out with the dory to explore what seemed the two rock islands close to shore—only to find them to be but broken small promontories, connected with the main. Explore next a grassy island not examined on previous visit—find it volcanic, rough—except for an elevated mass covered with vegetation and with a flat top. Not a vestige of anything human. Before finishing fog advances from land, until ship is lost from view. Recall everybody, call the dory which had to ride outside not to be damaged by the heaving water on the rocks—and return—nothing else to do. The Tanaga cave remains undiscovered.

Next day search rocks off west coast of the large island of Adak—no caves; but on the shore an extensive old site.

Explored on this trip also rock shelters in Korabelni Bay, Atka Island—a few skulls and skeletons, but main "cave" (rock shelter) despoiled.

Shiprock

A memorable item, however, still

awaited us. This was the visit—this time successful—to the great rock in the midst of the rough Umnak Pass, known as "Shiprock." Again it will be best to give the original notes, which preserve a flavor that can not be duplicated later.

Aug. 19. Reach off Shiprock at 9 A. M. Soon on a dory, and at 10:15 there. Beach all huge rocks. Find the little landing place Krukhov told about, go up steep slopes to overhanging cliffs and explore. Island larger than seems from distance, shore very rough. Luckily but little surf.

Soon find a great long rock overhang, and in it a structure of driftwood, with two skulls and some attached bones visible; and before long see it is an undisturbed deposit of mummies and burials. Excavate intensively whole day. Boat brings lunch and remaining boys. A great harvest, next to that of last year on Kagamil—and as then at practically the last day of the trip!

There were two separate shelters here with burials. In the main one, the bodies had been placed on a structure of driftwood poles and on a big portion of a whale skull. On this base lay three whale scapulae, then mummies, and over all this was an inclined roof of parallel partly dressed poles leaning against the wall; and this "roof" had once been covered with skins of sea-lions.

To the left of this main part were about five feet of later burials, males on top, females and children farther to the left and lower.

The mummies were much as those at Kagamil, but there were no children in their carriers and nothing remained in entirely whole condition. The bodies had been less well strapped, also, and there was less matting; but two of the mummies below their outer skin cover showed remnants of highly decorated skin dress and matting.

Had to send back for more sacks and burlap and cord. Quite a haul, and skulls of mummies *all of the oblong,*

MUMMY SHELTER ON SHIPROCK, UMNAK PASS

WITH DEPOSIT OF MUMMIES AT RIGHT BELOW AN OVERHANGING LEDGE. ON THE LEFT AND BELOW, AMONG THE ROCKS, OUR DORY MAY BE SEEN. APPROACH TO THE PLACE IS OFTEN IMPOSSIBLE.

pre-Aleut, variety. A highly important find, and undisturbed, only affected by age—though not excessively ancient. No trace of white man's influence, and no disease save arthritis.

Had to hurry—ship wanted to leave at 5—but after all stayed for us till after 6. Officers and men with us were very helpful. It is hard to give credit enough to the Coast Guard for all their aid.

Good many of the female and children's skulls on the side of the mummy structure showed the Aleut type—evidently later burials.

In second shelter, marked on surface by two posts and a nicely dressed crossbar, only regular burials, no wrappings, no objects, about six or more bodies and all Aleuts.

Evening. Had once more to telegraph for large barrels. Everything now stacked on deck, as last year, even though not quite so much.

As we finished, fog began to invade everything once more, and before we reached the ship with the last load the Shiprock could be seen no more.

When we reached the ship—6:30 P. M.—they were hoisting the anchor—water said to have been over 100 fathoms. This necessitated the dory's "staying off" in the now rough water for over half an hour. Tossing and rocking so much until the spine, from so much bending from side to side, felt like in a moderate attack of lumbago.

MUMMY DEPOSIT ON SHIPROCK ISLAND
THE MUMMIES ARE LOCATED ON THE RAFTERS UNDER THE ROCK LEDGE ON THE RIGHT. SIDNEY CONNOR AND ALAN MAY, TWO MEMBERS OF THE EXPEDITION, MAY BE SEEN.

SHIPROCK, 1938

Thanks, once more, to the Coast Guard, the search of main previously found burial caves could be resumed, and supplemented by that for new ones. The party on the small Cutter *Ariadne*, Captain H. W. Stinchcombe, left with the expedition June 1st, and June 2nd reached once more the Shiprock in the Umnak Pass.

June 2, 9 A. M. Spent fair night, now on dory for Shiprock. Cloudy, but signs of clearing. Sea so far moderate.

10 A. M. Have reached the rock, found everything as we left it. Excavate in farther depressions below overhang. Soon find more bones, Aleut burials. Continue till 12:30, when boat brings captain and lunch.

All skeletal remains found to-day from early Russian period—some large and small white glass beads deep among them. Most skulls and bones in poor condition, number of skulls broken to pieces. Some mixture of oblong (pre-Aleut) with rounded (Aleut) heads. The two strains have evidently intermingled on Umnak, and remnants of the larger pre-Aleut people were still here on the advent of the Russians.

With the bones found four flat stone lamps, a number of obsidian arrow points and scrapers and a few small chipped knives of other stone. One of the lamps has a handle, to the right of front, a turtle-like head and neck. An-

other, larger, is triangular. All of very moderate depth, fair to good workmanship, dark to black stone, resembling those of Kashega.

At our old rock-shelter, during lunch, found odd petroglyphs on one of the large rocks. Also red paintings—lines and curves—on various parts of the base of the whale skull that we got out of the shelter last year. Did not see these artifacts last season due to dirt on the objects.

Explore all around the rock—no caves or other rock shelters.

Start back 3 P. M. Day clear, beautiful view of the S.E. Umnak as well as the Unalaska volcanoes; but windy and water now rough, with great current. Captain, fearing accident, has us discharged on the island opposite (Umnak), and with us walks about 5 miles over beaches, rocks, tundra, with stiff wind against us. Have to cross a swift thigh-deep stream, could hardly keep upright. Walk takes over 2½ hours. Then dory picks us up, through surf, and we start on rough trip to the cutter. Before we can reach it however are caught by a "willy-wow," violent localized wind, driving cold spray at times clear over our heads. All wet. Bump into cutter and there is quite a time in getting us out and the dory on the ship; fortunately dory new, men efficient and so no bad damage. But a trip not for weaklings.

After 6, supper—not much appetite after that walk and run. Stay overnight at anchor—a gale, and sea rough.

ALEUTIAN MUMMY, FROM SHIPROCK

ALL THESE MUMMIES WERE BURIED IN THE "CONTRACTED" POSITION, DRESSED IN SKIN GARMENTS COVERED WITH MATTING OR SKINS AND TIED.

KAGAMIL

June 5. Bright morning. Umnak NW. Volcano, Vsevidov, glorious. Finally get to inner harbor of Nikolski—was too rough yesterday. Arrange for later work—get a couple of specimens from boys—and after 9 start once more for Kagamil, to satisfy finally about hazy report of additional cave.

Reach after 1—divide party—explore coasts for over two miles to northeast and up to near vertical cliffs to west—no cave. But a small old village near trapper's hut and another in a northeast bight—neither important. Examine also rock shelter in side of hill behind and to west of hut—nothing there.

Many beautiful views during the day of the Umnak volcano, and somewhat also of Mt. Carlyle. Once saw, too, the upper part of Mt. Cleveland, with a small wreath of smoke from top. Could not revist our caves, which still attract—perhaps later in season.

June 6, 8 P. M. Start once more for Amlia. Sea fairly good at first, but soon

THE "GANG" LUNCHING AT THE MUMMY SHELTER ON SHIPROCK IN 1937
THE DIGESTIVE ORGANS OF PERSONS IN THESE REGIONS ARE NOT PARTICULAR, IF THERE ARE SUBSTANTIAL SANDWICHES AND PLENTY OF HOT COFFEE.

rough, large waves, ship rolled much, kicked, bumped, shivered. Whole night so, more or less, and morning worse. At breakfast everything sliding and knocking—no meal. By near 9 pretty near sick; but at 10 enter Sviechnikov's harbor in south coast of Amlia—a great relief to all; but weak, and stomach bad.

After lunch — poor lunch — mouth muddy—leave for headland. Search and climb over slippery rocks, and at last find the cave—a big orifice in base of huge basalt bluff, in a ravine. Cavity largely filled with rocks, among which traces of some mummies—could not have held much—but what there was has been despoiled. A search among and under the rocks gives two damaged female Aleut skulls, some bones and a nice large wooden dish. Search all neighborhood —nothing further.

Kanaga

June 9. Heard of a burial cave on the Kanaga Island. Leave Amlia 4 A. M. Rough. Ship rolls and tosses so that sleep or meals impossible.

Afternoon fog in addition, but sea slightly better, though big ugly waves. After 5 a partial clearing, just enough to enable us to pass safely into the little Kanaga harbor. Entrance narrow, rocks both sides, wreck of the U. S. S. *Swallow* on those of the left, dismal, washed and sprayed over by angry waves. A sombre sight.

June 10. Gale from NW, impossible to lower dory. Men of little local Navy station know several sites—we get a number of skulls and a skeleton—but no cave. Hear of one on south coast of the island, but distant and information not definite enough.

Ilak

June 11. Morning quiet; sun, nice, mild. Leave 7 A. M. for another visit to Ilak to make sure nothing was left—but stop for some time to examine the wreck of the *Swallow* and salvage some things.

Reach Ilak after lunch, explore till 6. Revisit the two caves—nothing left in them but a few stray bones. On a bluff at the southeast end, however, facing a smaller island, I find an old village site, not known of before.

In the afternoon sky gets clouded, southeast wind rises, gets stronger, and by the time we are through ship had to be moved out of the wind. A rough getting back and especially aboard; but all ends well.

To-morrow Amchitka. No possibility as to Tanaga.

Last Visit to Kagamil

Between June 11 and August 10 the expedition excavated at Amchitka and Umnak, and surveyed for old sites on the Commander Islands. On Aug. 10, on the Cutter *Shoshone*, Captain J. Trebes, r., we reached once more the Four-Mountain Group, to have a last look at our caves.

The weather is rough and foggy. Reach the islands, but can not anchor—keep going about till morning, then anchor near foot of Mt. Cleveland (but partly visible at any time). During day a bad SW "full" gale—no possibility of doing anything—wind 60 miles an hour.

Aug. 11. Gale over, though still much swell. Ship goes over to Kagamil, anchors off the rough shore, and soon we reach with dory the cove where we em-

AN ALEUT COUPLE IN ALASKA

THE MAN IS WEARING A TYPICAL OUTER GARMENT WITH DECORATIONS, AND A TYPICAL DECORATED WOODEN HAT. THE DRESS OF THE WOMAN HAS ALREADY BEEN MODIFIED BY RUSSIAN INFLUENCE. THE MAN REGRETTABLY DOES NOT APPEAR TO BE AN ALEUT BUT IS RATHER A NEGRO IN ALEUT CLOTHING AND HAT. (AN OLD DESIGN BY CHORIS.)

barked the second day in 1936, and are confronted with the same old huge bad slippery boulders. Examine two miles of roughest shore, to beyond warm cave, revisit both caves, and excavate, get in recesses of rocks 5 more skulls, some bones, 2 long bone dart harpoons, a stone lamp and a few other specimens. Light rain most of day, get all wet from grass; but in warm cave fairly comfortable, and at 4 back to the ship. Officers and men from ship helped again all along, all most friendly. In the warm cave, below all the mummies removed in 1936, under a great slab—it took four of us to lift it—found an additional cremation burial of a woman and a child, doubtless sacrificed slaves. Layer of burnt bones however extended over a large space farther—below all former contents of main part of cave—and showed the calcined remains of more victims—apparently almost all females—possibly as many as ten individuals. An interesting fact was that the fire in which the bodies were burnt was not that of wood, which in these parts is non-existent, but of cancellous whale bones rich in fat. The bones of the cremated were short and rather weak, Aleut-like; but one much burnt skull in pieces, taken for reconstruction, has shown the type of the pre-Aleut people. The next day back to Umnak, where we found a whole great pre-Aleut mound.

Scientific Results

The scientific results of our cave exploration in the Aleutian Islands can not as yet be fully appraised, for it will take long for the materials to be studied. What can be said in general, is as follows:

Notwithstanding the ravages of time,

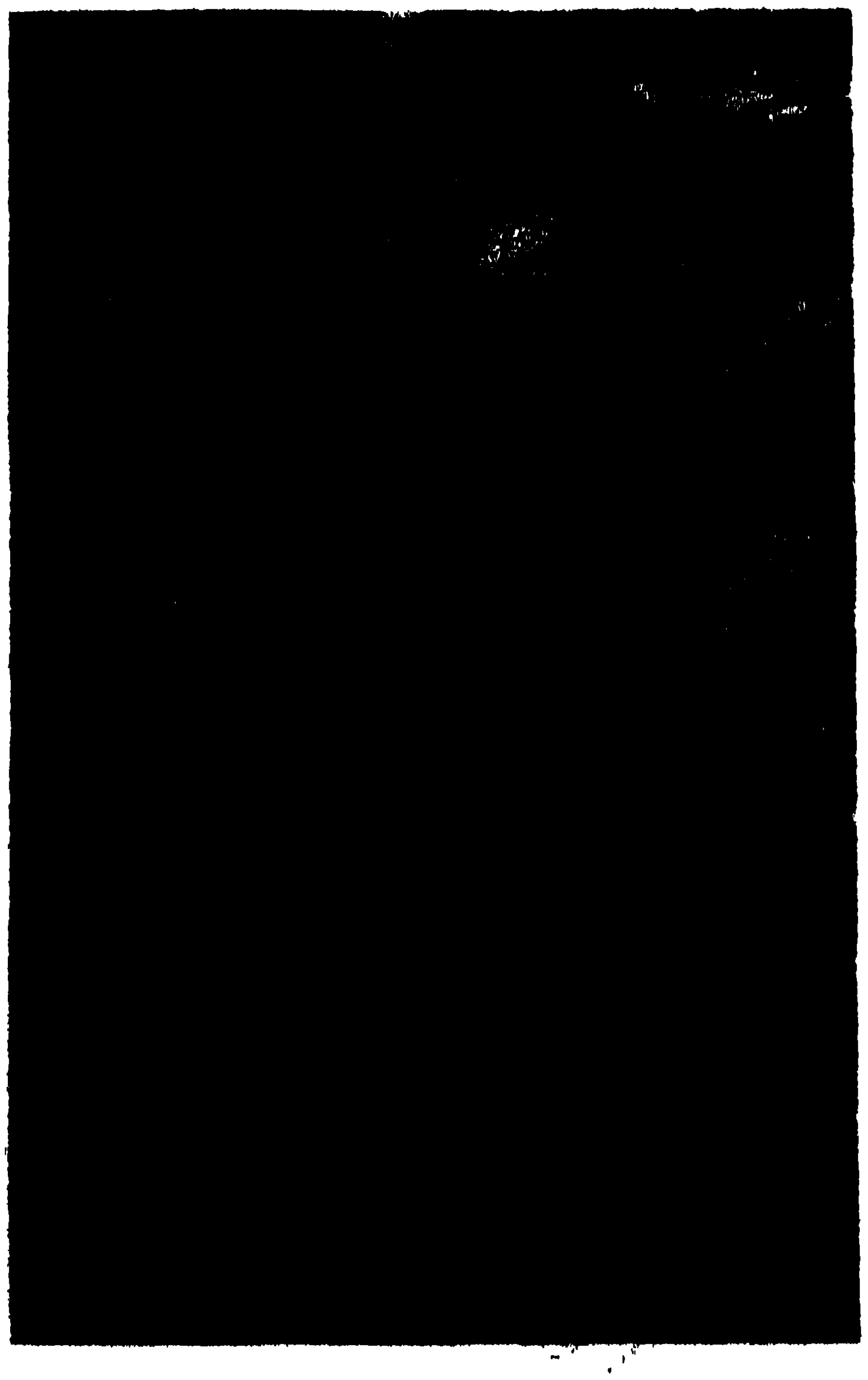
AN ALEUT PAIR, SHOWING THE TYPICAL NATIVE MALE AND FEMALE DRESS AS WELL AS THE TYPICAL ALEUT WOODEN HAT. THE FIGURE ON THE RIGHT SHOWS THE PHYSIOGNOMY OF A WHITE WOMAN—PERHAPS A RUSSIAN-ALEUT HALF-BREED. IN THE BACKGROUND THERE MAY BE SEEN TWO *baidarki*—NATIVE CANOES. (AN OLD DESIGN BY CHORIS.)

ALEUTS OF MIXED BLOOD
MAINLY RUSSIANS, ON THE ISLAND OF UMNAK. THESE PRESENT-DAY "ALEUTS" ARE A WEAKENED LOT, AND ARE SUBJECT TO MANY WHITE MAN'S DISORDERS.

and extensive vandalism by trappers and other white men, a considerable amount of the old remains, skeletal and even cultural, have been preserved and saved.

The number of skeletons and skulls from the found caves reaches several hundred. The mummies alone counted over 70. The latest of these remains are doubtless from the earlier part of the Russian period, the earliest materially antedate it; but none are older than the second millenium, and probably the second half of the second millenium, of our era. As none of the other mummies or remnants of mummies that so far were found in the Aleutian caves showed any greater age, it is inevitable to conclude that the practice in the islands was not very ancient. It is true that there may be mummy caves not yet discovered and the contents of which may throw further light on the subject. It is further quite probable that the mouths of other such caves have been sealed forever by falls of rock during earthquakes. But had the practice been ancient at least some of the caves that were found would have shown it, for they were old formations.

The mummifications and cave burials were practiced by the Aleuts up to and for some time even after the advent of the Russians. The proofs of this are the presence in a few of the latest burials in the Kagamil caves of syphilis, which was wholly absent in the mass of the earlier material; also the find in one of the caves, with superficial remains, of remnants of an old-fashioned "shoe-



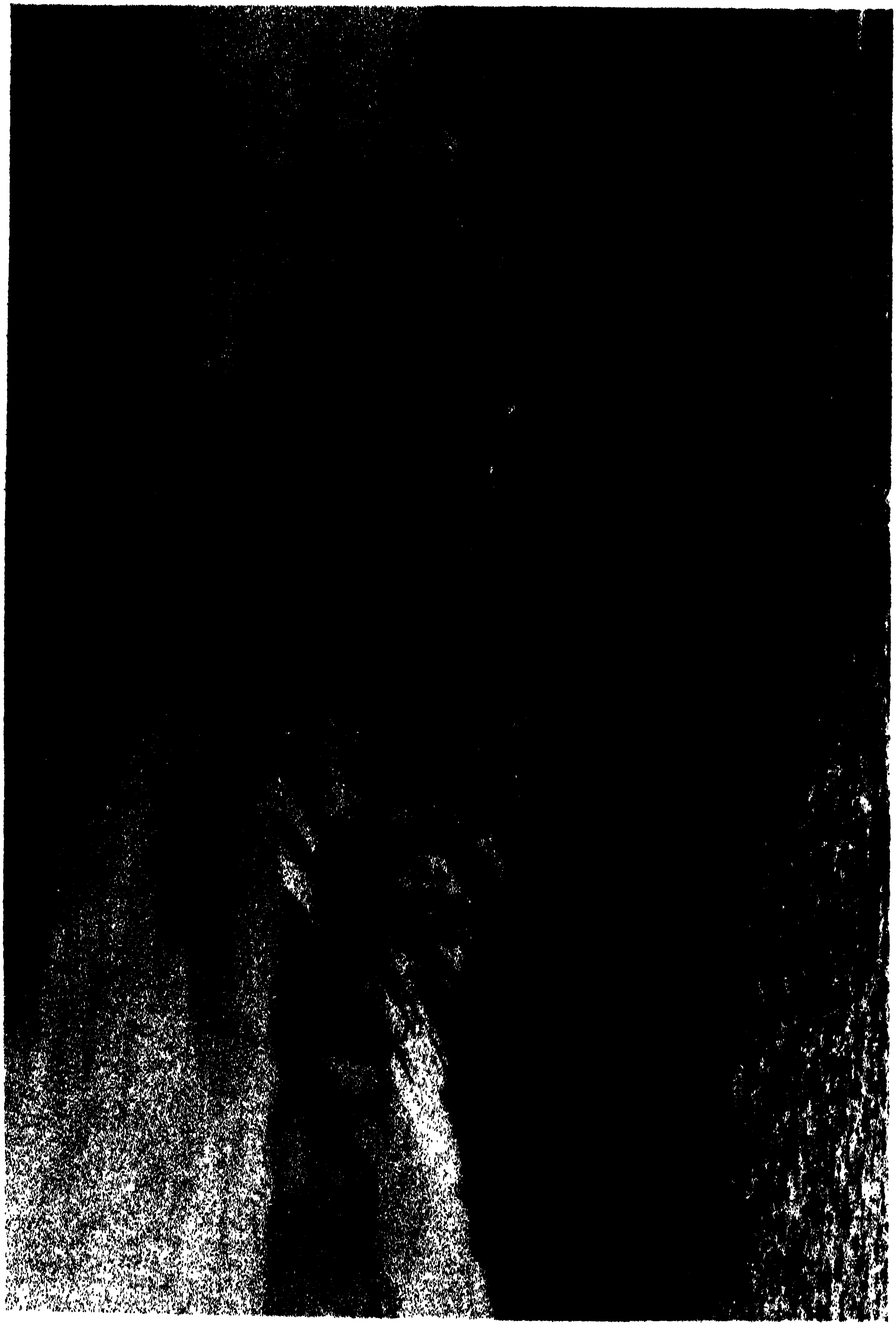
THE HOT MUMMY CAVE ON KAGAMIL
APPEARS FROM THE OUTSIDE TO BE A HUGE SLIT IN THE LAVA DEPOSITS, BUT INSIDE IT ENLARGES INTO A GOOD-SIZED IRREGULAR CAVITY. TWO MEMBERS OF THE EXPEDITION MAY BE SEEN IN FRONT OF THE ENTRANCE TO THE CAVE.

ALEUTS OF MIXED BLOOD, PARTLY RUSSIAN
TWO OF THE STURDIER YOUNG MEN, WORKING IN THE SEAL INDUSTRY ON THE PRIBILOV ISLANDS.

maker's'' iron-bladed knife, and also of a piece of a white man's cord.

The introduction of the methods of both mummification and cave burials was apparently due to the easily identified broad-headed Aleuts. The islands, it is now definitely established, had had for many hundreds of years before the Aleuts came, an extensive pre-Aleut population of taller, oblong-headed, more Indian-like people. It is now certain that all the older sites throughout the islands belong to the pre-Aleuts, though Aleut remains may be found in many on the top. The Aleuts, it seems, could hardly have been in the islands for

THE INHABITANTS OF ATTU VILLAGE
ON ATTU ISLAND, WESTERN-MOST OF THE ALEUTIAN GROUP. (U. S. NAVY.)



MOUNT VSEVIDOV ON UMNAK ISLAND

ONE OF THE MOST STRIKING VOLCANOES. THE TOP OF THE MOUNTAIN WAS BLOWN OFF LONG AGO. (C. & G. SURVEY, 1938.)

more than perhaps three hundred years before the advent of the Russians. The great "middens" which by Dall and Jochelson have been thought to be Aleut now appear generally with but an Aleut veneer but with the bulk pre-Aleut.

There is no indication that these sturdier pre-Aleuts perished or were massacred by the newcomers. They probably moved eastward, to the continent. They had not practiced mummification or cave burial during their stay in the islands before the advent of the Aleuts. But, especially on Umnak and the more western islands, the last pre-Aleuts who were still there when the Aleuts came, mingled and mixed with these and adopted some of their customs, including to some extent—especially at Umnak, it is evident—the new form of burial. Thus at Shiprock (Umnak Pass) the mummies—males—were pre-Aleut, while directly by them there was a mass of burials of Aleut women and children. In the Kagamil caves, while the Aleuts predominated, there were both types and some intermediates. One cremated slave in the warm cave was, it could be determined, pre-Aleut, while the others, so far as could be told, were of the Aleut type. And similar indications of a brief coexistence of the two types were given by other islands. Shortly after the advent of the Aleuts the pre-Aleut strain disappears; yet to this day a few traces of it seem to occur among the living western Aleuts.

ALEUTS OF MIXED BLOOD

THE MAN IN THE CENTER COMES NEAR TO THE OLD TYPE. THE REST HAVE MORE OR LESS WHITE BLOOD, MAINLY RUSSIAN.

From where the Aleuts brought or got the usages of mummification and cave-deposits of the bodies, is uncertain. No such habits as yet are known of in north-eastern Asia; and similar procedures further to the eastward—on Kadiak, in Prince William Sound, on the islands of SE. Alaska and British Columbia—do not appear any older or even as old. The whole custom may have gradually developed among the Aleuts themselves.

FOUR-MOUNTAIN ISLANDS, LOOKING SOUTHWEST FROM ULIAGA

MT. CLEVELAND IS ON THE LEFT, MT. CARLYLE ON THE RIGHT. HERBERT ISLAND IS VISIBLE IN THE DISTANCE.

Nothing whatever of that nature is known from among the Eskimo, or the mainland Alaska Indians.

The mummy bodies without exception were in the typical contracted or "fetus-in-the-utero" position, with the limbs folded close to the body, the hands under or on the face, the head bent a little forward. The little children were in skin- or basketry-like carriers, premature births in small bundles or wooden dishes.

Specimens with the mummies were numerous, and some were of high interest. They ranged from whole kayak skeletons—paddles, war-shields, pieces of armor, garments, dart-shafts, baskets, bags and a wonderful assortment of matting, some exquisitely made and decorated, to fine labrets and spoons, and some common stone lamps and utensils. The abundance and variety of the perishable objects amounted to a veritable

MOUNT TULIK, A SLEEPING VOLCANO, ON UMNAK ISLAND
TAKEN FROM UMNAK PASS. (C. & G. SURVEY, 1938.)

resurrection of an important part of the old industries and give a radically new light on the Aleut culture.

The bodies were wrapped in sea-otter fur or bird-skin robes (parkas) and mats, the whole bundle being tied into another mat or a sea-lion skin, laced together or tied with interestingly made cords, or with ropy kelp.

The bundles so far as perceptible had not in general been suspended, but lay close in a mass or on rafters; some may possibly have been hung from the drift-wood posts in the cold Kagamil cave, but no mark remained of such a suspension.

The adult mummies, some still in a very good condition, showed each a rough opening, some through the perineum, some through the upper part of the chest, through which doubtless the viscera were extracted. In no case, however, from any locality, was there any remnant of a stuffing of the body. Such stuffing, if practiced, must therefore have been limited to some locality from

which there is no representation, or has in the course of time completely disappeared.

In at least two cases, both from Kagamil, there was preserved an individual skull, once in wrappings, once in a wooden dish in moss. The latter, which alone so far was examined, is the skull of a young adult female without the mandible, lying snugly in the moss on its right side. It was evidently preserved thus already as a skull. These may have been trophies, or skulls of especially loved or esteemed individuals.

The deposits in the warm cave on Kagamil gave also an abundance of loose feathers of several varieties of birds, a good many dried wings, and even some dried whole birds. These were doubtless offerings. One wooden dish contained no less than 18 dried wings of the "pine-grosbeak," another a dried brown hawk skin. And there were a number of dishes with odds and ends of woman's work.

Among many loose skulls in the humid cold cave of Kagamil was one, normally developed, of a very extraordinary size (2005–2010 cc capacity). As there were no outstandingly large bones in the cave, this skull could not be attributed to any giant, which makes it the more remarkable.

The study and description of all the cultural material will require much application and must be left to the experts on such matters.

Conclusions

Our expeditions in the Aleutian Islands, under the auspices of the Smithsonian Institution, have located and explored a series of mummy or burial caves and rock-shelters, which yielded collectively a large amount of both skeletal and cultural materals.

The mass of these materials are from pre-Russian Aleuts; but the latest burials in the caves or shelters were post-Russian; while among the earlier ones there was a scattering of the pre-Aleut people.

The mummies and burials included both sexes and all ages; but there was noted here and there some segregation.

The mummies in general had not been suspended, but laid one upon the other, or side by side, on tiers of driftwood.

The adult mummies showed openings, either in the lower part of the pelvis (perineum) or in the upper part of the thorax, through which presumably the internal organs were removed; but in the specimens found there were no remains of any stuffing.

Beneath or to the side of the mummies and burials there were repeatedly found, both in the caves and the rock shelters, cremated remains of humans, probably slaves, but mainly women and children.

The cultural materials recovered show a high degree of ability and even artistry, not excelled in similar lines anywhere else on the American or other continents.

The introduction of the practice of partial mummification of bodies in the Aleutian Islands must be attributed to the Aleuts; but where or when it originated remains a problem for future determination.

THE WHITE DWARF STARS

By Dr. DIRK REUYL

LEANDER MCCORMICK OBSERVATORY, UNIVERSITY OF VIRGINIA

"Twinkle, twinkle, little star,
How I wonder what you are . . ."

SOME twenty-five years ago the first white dwarf star was discovered, a spherical mass of gas with a familiar white-hot surface, of some 8,000° absolute and a presumably acceptable interior temperature of several million degrees, but . . . of a density several thousand times greater than the earth's precious solid platinum.

In spite of refined researches with great telescopes, even to-day the total number known of this astounding type of stars is a mere score, a fact illustrating the difficulties met by the observational astronomer. Greater still are the obstacles confronting the theorist attempting to solve the riddle of the internal constitution of these stars. It must be said, therefore, that the problem is still far from a solution, and perhaps has not advanced beyond a rather elementary stage. However, from its spectacular beginning it has been a problem of paramount importance to physicists as well as to astronomers.

No doubt the problem presented by the white dwarf stars deserves even wider attention, in view of its close connection with theories of stellar evolution, theories of atomic structure, and other problems of more general interest. While writing this, I find that my contention is proved by a full page article in a recent issue of "Amazing Mystery Funnies." The reader will find there, immediately preceding the "Phantom of the Fair," the factual description of a white dwarf, interestingly adorned with pictures of steam shovels and derricks for moving ponderable things. Knowing that the white dwarf stars have penetrated the American home, I feel justified and encouraged to carry on with this article.

Let us go back, not a mere twenty years, but rather some twenty centuries and note that observations of stars' positions were made by Timocharis, Aristillus and Hipparchus, a few hundred years before the birth of Christ. When, in 1718, Halley compared these early positions, as given in Ptolemy's Almagest, with the observations made in his day, he discovered that small changes had taken place. The "fixed" stars are in very slow motion with respect to one another, and we have here the discovery of the "proper motions" of the stars, a phenomenon which Halley described as "not unworthy of consideration." Proper motion of a star is its apparent motion across the line of sight as seen from the earth.

The brightest star in the sky, Sirius, one of the stars studied by Halley, in a curious and devious way gave rise to the problem of white dwarfs under discussion. More than a century after Halley's discovery, Bessel, in 1844, announced the variability of the proper motion of Sirius, which he had suspected since 1834. Sirius while traveling through space, rather than going straight like a well-behaved star, was found instead to move along a wavy line; not in a short period or with large waves, but in 50 years and a barely observable variation from a straight line. The influence of a sinister companion would indeed explain the erring behavior of Sirius, for Sirius and a companion would revolve around their common center of gravity as they move through space. Only the companion, though quite systematic in its gravitative effects on Sirius, had been elusive from observers. Its position was neatly com-

puted by Safford, in 1861, and the next year it was actually seen close to its predicted position by Alvan G. Clark, the lens maker, in testing the refractor now at the Dearborn Observatory. Sirius and its companion, conveniently called Sirius A and B, then became easy prey for a score of investigators, all hungry for facts about this exceedingly interesting system. Soon the orbits of A and B about their common center of gravity were computed, as also their relative masses. The total mass, through Kepler's harmonic law, is known when we combine their known distance from us with the distance between them and the period of their revolution about their center of gravity. The determination of the parallax at the Leander McCormick Observatory is one of the several values obtained to anchor the star down in space. And also the apparent brightness was studied at McCormick by Dr. Vyssotsky, who was able to secure excellent photographs of this exceedingly difficult object, in close proximity to brilliant Sirius A but some 10,000 times fainter.

Let us now return to the results of the careful weighing of Sirius A and B. We find that the total mass of both stars is 3.39 times the sun's mass, Sirius A getting 2.44 and Sirius B 0.95, or almost that of the sun. And at once we notice how strikingly the near equality of the masses contrasts with the enormous difference in rate of radiation—a mass ratio of 3.7 to 1 and a radiation ratio of 10,000 to 1. Or, if we want to compare this faint companion with our sun, we have to explain the fact that Sirius B is more than 200 times fainter than the sun although it is of approximately the same mass. This difficulty could easily be overcome by assuming Sirius B to be a red dwarf star of so-called M type, *i.e.*, of low surface temperature, say about 3,000° absolute. Its inseparable friendship with the white star Sirius of type AO, corresponding to a surface temperature of 11,000°, need not worry us. Truly peace reigned supreme again after all the blame for Sirius' disorderly conduct had duly been placed upon its companion.

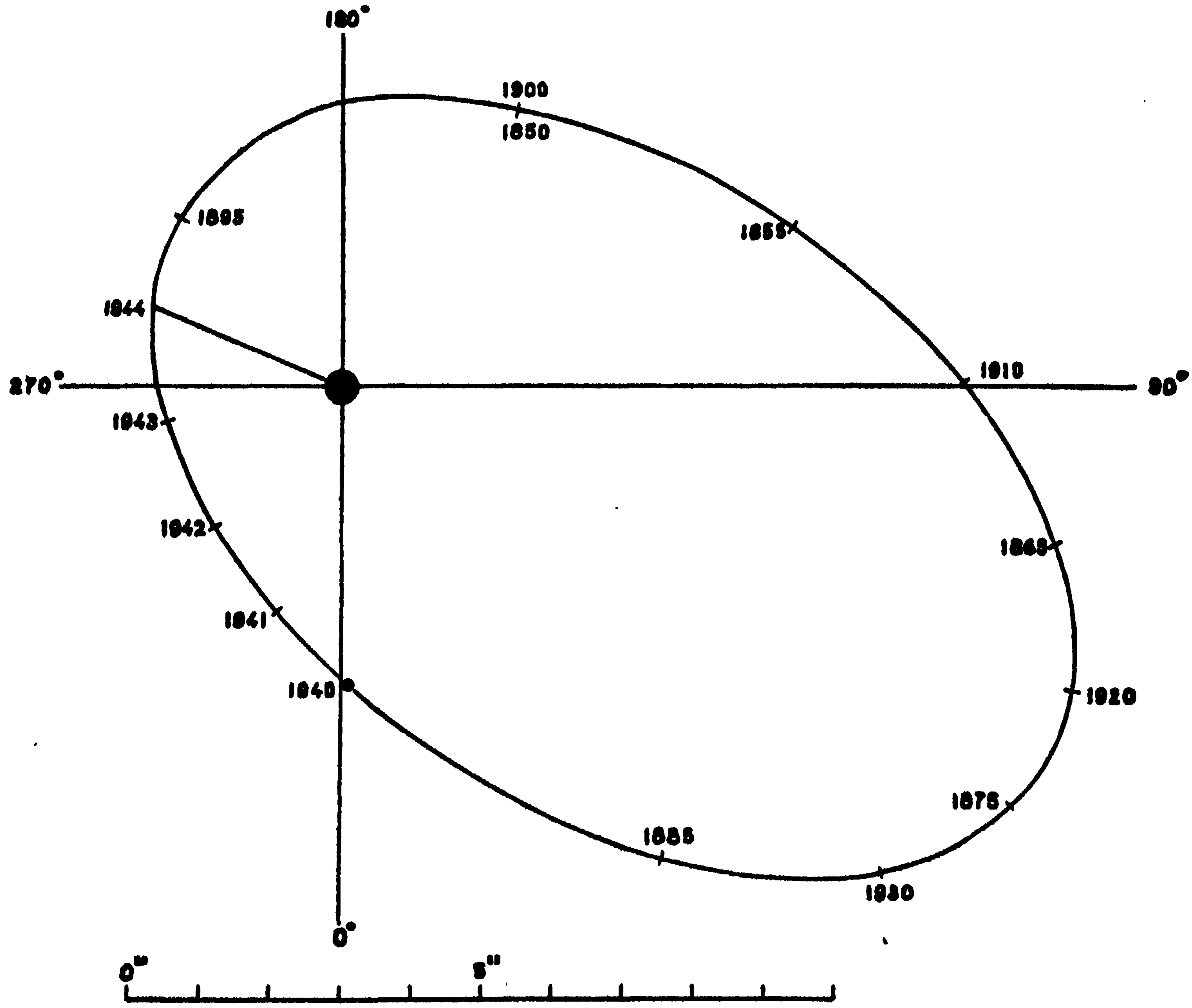
But this quiet proved to be only the lull before the storm which broke loose in 1915 when Adams made another startling discovery on this star. He succeeded in photographing the spectrum of Sirius B, a very difficult observation even with the great reflectors of the Mount Wilson Observatory. He classified the spectral type as A7, corresponding to an effective surface temperature of about 8,000°, and therefore of somewhat "later" type than Sirius A; in other words not quite so white hot, but with a touch of yellow. The world—that is to say the small brotherhood of astronomers on their planet, to be more specific—became badly upset by this announcement. Let us analyze why this sub-class No. 7 of type A caused such a commotion. We must first introduce the bolometric magnitude, a measure of the total radiation over the entire spectrum of a star, as contrasted with the visual magnitude, which gives the star's energy only in visual light, a rather limited range of wave-length in the yellow.

Sirius A, of type AO or effective surface temperature of 11,000°, has an intrinsic brightness given by the absolute bolometric magnitude 0.97 on a scale on which the sun has the value 4.85. Translating this into ordinary terms, we find that Sirius A radiates 36 times more energy than the sun. Since the effective surface temperature of the sun is 5,700°, we find that the radiation of Sirius A *per unit area* is 15 times that of the sun, since radiation per unit area is proportional to the fourth power of the temperature. Therefore the ratio of the areas of Sirius A and the sun is 36/15 = 2.4, and, therefore, the ratio of their radii is the square root of 2.4, or 1.5. We are satisfied that

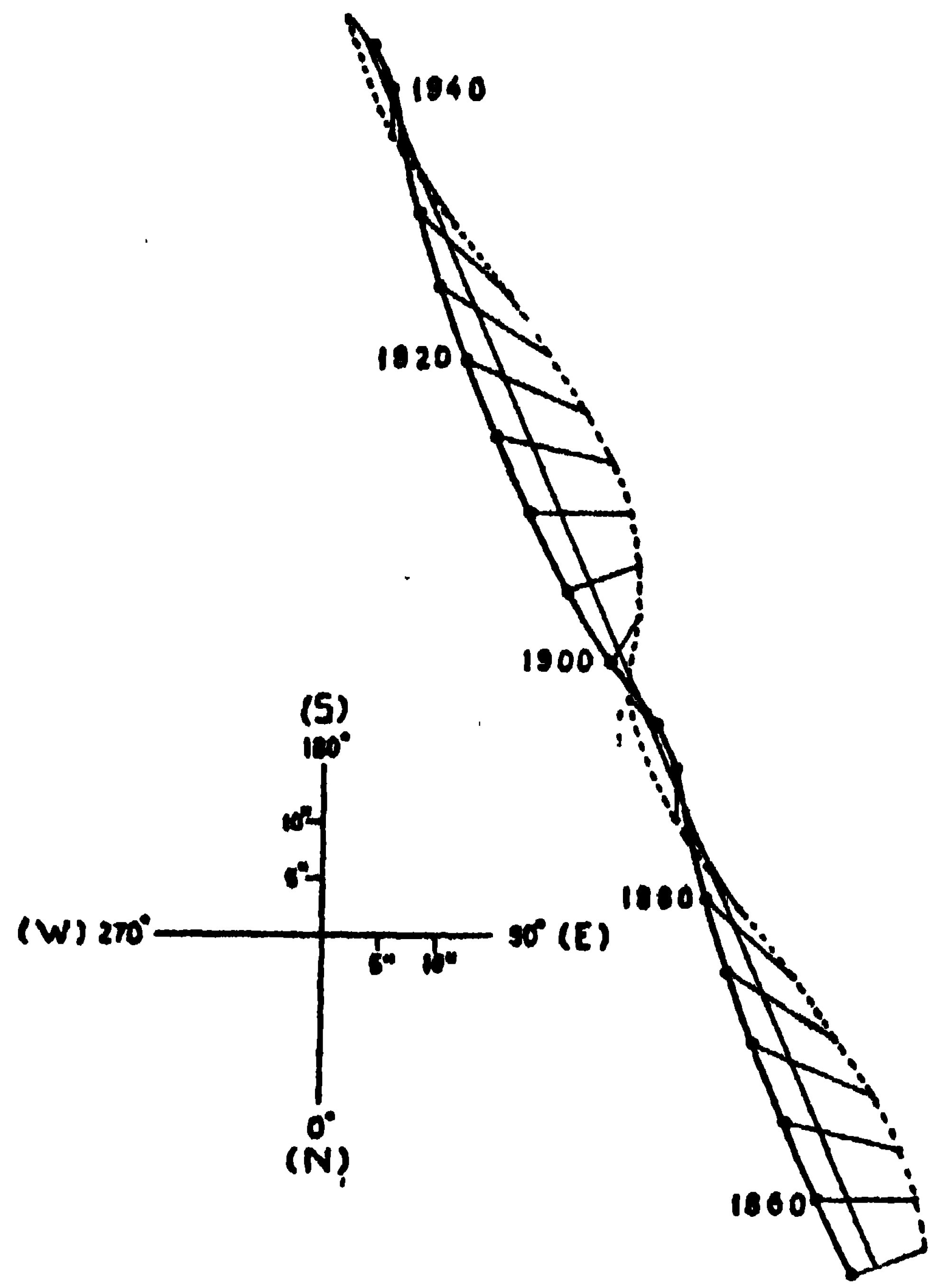
Sirius A with this radius and a mass of 2.44 solar masses may be considered a very reasonable star.

Let us now apply the same calculation to our trouble-maker, Sirius B. It is of type A7, or has a temperature of 8,000°. Comparing its faint absolute bolometric magnitude with that of the sun, we find that its energy output is only 1/360 that of the sun. Yet, because of its high temperature the radiation per unit area of Sirius B must be considerable; in fact, 3.8 times that of the sun. This leads to a ratio for the areas of $\frac{1/360}{3.8} = 1/1400$ and for the ratio of the radii 1/37. That is, Sirius B is found to be a dwarf star with a radius of only 19,000 kilometers, or less than three times the radius of the earth. This may sound startling, but matters become definitely alarming when we realize that an amount of gaseous matter practically equal to the mass of the sun is crowded into a sphere with a volume 50,000 times smaller than that of the sun. If we have managed up to now to stand up under the strain, we may sit down and calculate the densities of Sirius A and B. We find that the average density of Sirius A is about that of water, but that the little Sirius B has a density about 70,000 times as great—a cubic inch of it at the surface of the earth would weigh roughly a ton.

At this point Eddington admitted that it would seem reasonable to dismiss the conclusion as absurd. However, he chose to attack the problem theoretically. Among the first approaches was to find whether the certain consequences of Ein-



APPARENT ORBIT OF SIRIUS B AROUND SIRIUS A. THE PERIOD OF REVOLUTION IS 50 YEARS.



WAVE MOTIONS OF SIRIUS A (FULL CURVE) AND SIRIUS B (DASHED CURVE). THE CENTER OF GRAVITY OF THE SYSTEM TRAVELS ALONG THE STRAIGHT LINE AT UNIFORM SPEED.

stein's theory of relativity actually existed. When light waves pass through a gravitational field their frequency is decreased; in other words lines in the spectrum will be shifted toward the red. Since the effect is proportional to the mass and inversely proportional to the radius of the attracting body, we find that Sirius B provides an excellent test case, because the predicted effect is 34 times that of the sun. This would produce a shift in the spectral lines corresponding to a velocity in the line of sight of about 20 kilometers per second. Fortunately we are dealing with a double star system, and hence by making differential measures between the spectral lines of A and B, the line of sight velocity of the system as a whole does not enter into the picture. Adams observed a shift of 23 kilometers per second, which leaves us, after allowing for 4 kilometers per second due to orbital motion, with 19 kilometers per second as the observed relativity displacement. As Eddington explained, the observation by Adams killed two birds with one stone, not only in giving a splendid confirmation of Einstein's relativity displacement, but also in proving the extremely dense condition of Sirius B.

How to explain this condition is another matter. Eddington reasoned that the only satisfactory solution would be in assuming the gas to be in a state of complete ionization; that is, the atoms are not only stripped of their outer electrons but of their inner ones as well. Under normal conditions the electrons remain in their places and keep their proper distances, leaving a great deal of empty space in the atom of which they are members. Under extreme ionization they become independent individuals and are free to crowd together into the superdense material which constitutes the white dwarf interior. At once Eddington was confronted with a new riddle. How can the gaseous matter cool down and finally turn into the state of an ordinary solid composed of atoms? In the change into atoms the star will have to expand to a radius ten times larger against the force of gravitation, and therefore it will *require energy in order to cool!* From where is this energy expected to come when ultimately the supply from the interior becomes exhausted?

Quoting Eddington, we must indeed "imagine a body continually losing heat but with insufficient energy to grow cold!" "I do not see," remarked Eddington, "how a star which has once got into this compressed condition is ever going to get out of it."

The solution as given by Fowler in 1926, sounds simple enough. The star never does get out of this condition, but with its high density and relatively low surface temperature must be considered a gas in "degenerate" state. Work by Fermi, Dirac, and later by Lindemann, has been utilized by Milne, who points out that the ultimate fate of the particles

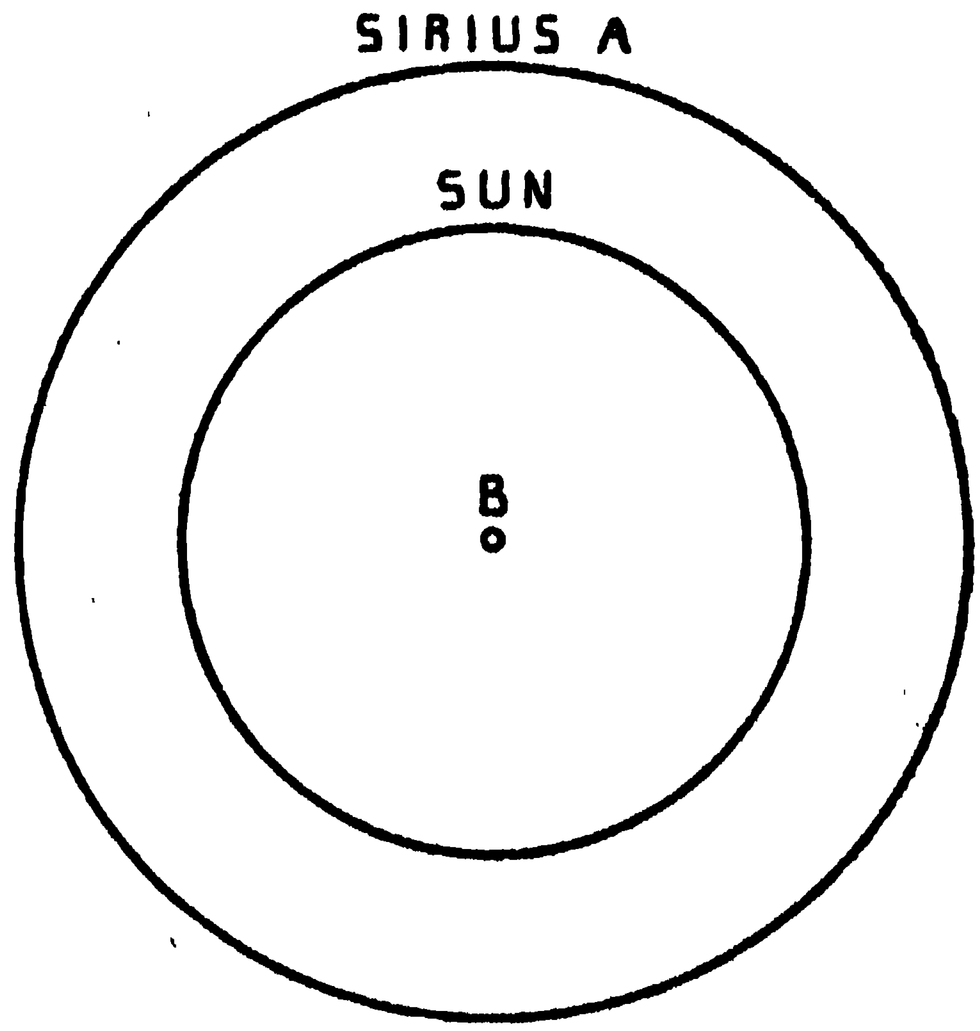
in such a state is complete organization. We shall then have a manifestation of the highest degree of atomic order and regimentation. "Freedom is non-existent, the final state represents atomic civilization in its highest form—or its lowest form, if my hearers prefer," quoting Milne from his Halley lecture, delivered on 19 May, 1932. According to Fowler, the white dwarf at the end of its life, in other words, completely degenerate and at the absolute zero, is analogous to one gigantic molecule in its lowest quantum state. The meaning of temperature has vanished; it may well be called zero.

The reader will observe that this final state offers a condition for which the extent of ionization may at the same time be called complete and zero! The particles, first liberated under a communistic white dwarf régime can only find that ultimately they must die in complete subordination, to the totalitarian state of the "black" dwarf. To reach this final stage of "black" dwarf, Milne suggests that the star in its white dwarf state consists of a degenerate core surrounded by a shell of ordinary gas. This non-degenerate shell, in cooling would exhibit the gradual reddening of the star. Simultaneously, its composing matter would gradually turn from the normal into the degenerate state, until finally the entire star had become degenerate.

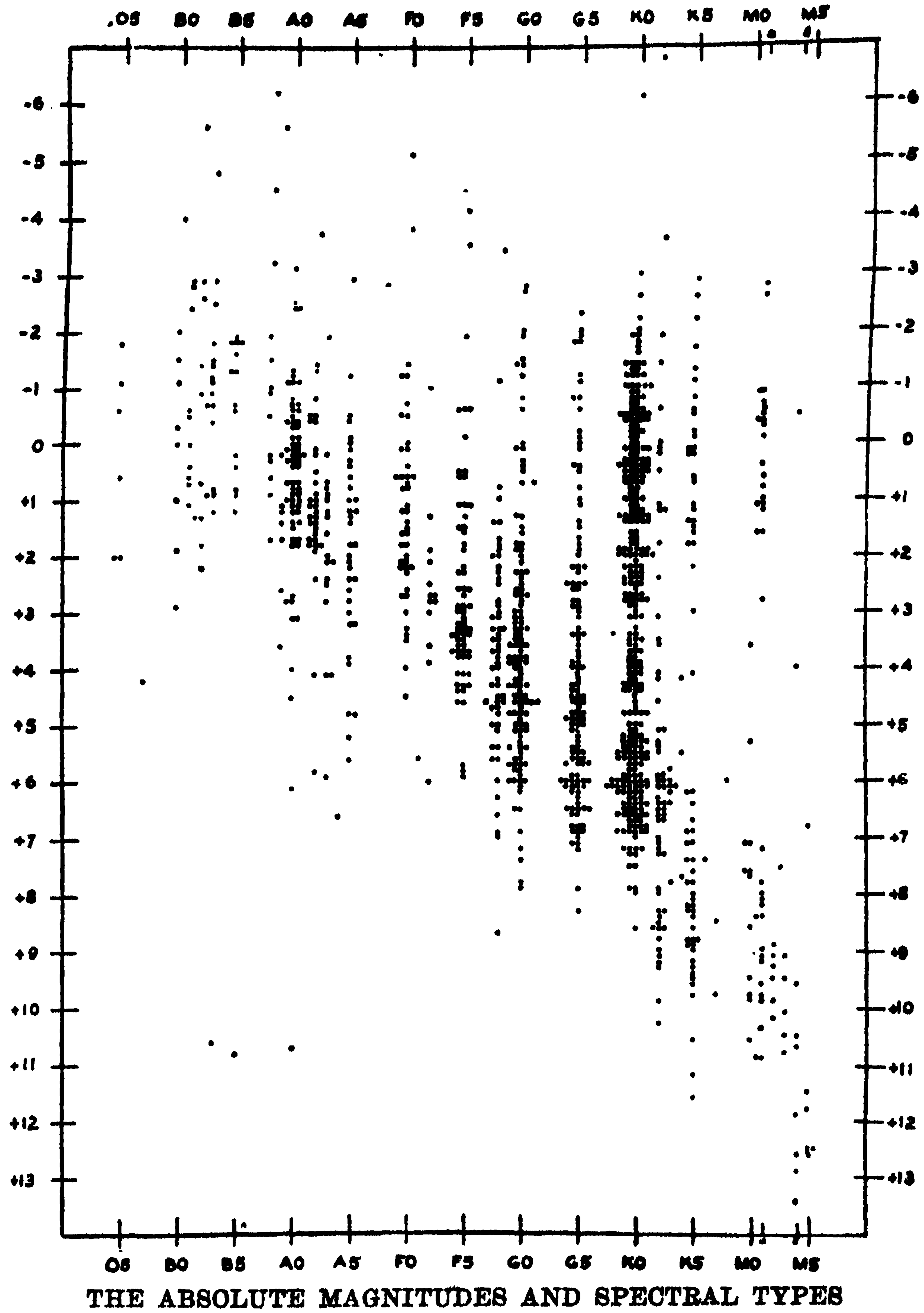
We must now do great injustice to further valuable theoretical investigations by leaving these aside in order to use the remaining space for a review of important recent observational work.

In surveying the spectra of the known nearer stars, and of those suspected of being near-by, Kuiper and others have discovered a considerable number of white dwarf stars. Because of their small size, the stars are faint, in spite of their comparative nearness, as stellar distances go, making the difficulty of detection very great. Whiteness of these faint, presumably near-by stars is, therefore, the first criterion. Spectral characteristics, such as lines widened by the Stark effect and of unusually great intensity in the violet, are practically conclusive. If the star lies within reach of the great "parallax" telescopes, the determination of its distance will serve to settle matters definitely. Not only for Sirius B, but also for four other white dwarf stars, was the parallax determined at the McCormick Observatory. For two of Kuiper's recently discovered stars the distances, substantiating the white dwarf character, have been determined by the writer. Several more stars are under observation, leaving untouched only those for which, on account of their extreme faintness, exposure times would become prohibitive.

The white dwarfs found up to date, though small in number, show conclusively some degree of variety in their spectra, some being bluer, others more yellow. Knowledge of their intrinsic luminosities, from apparent brightness and parallax, is imperative in order to study their place in the scheme of stellar evolution.



RELATIVE DIAMETERS OF SIRIUS A, THE SUN AND SIRIUS B. SIRIUS A HAS A MASS 2.4 TIMES THAT OF SIRIUS B WHICH IN TURN HAS A MASS EQUAL TO THAT OF THE SUN.



THE ABSOLUTE MAGNITUDES AND SPECTRAL TYPES

FOR 1206 STARS FOR WHICH PARALLAXES HAVE BEEN DETERMINED AT THE LEANDER MCCORMICK OBSERVATORY. THE THREE POINTS IN THE LOWER LEFT-HAND PART OF THE DIAGRAM BELONG TO WHITE DWARF STARS.

I will not discuss all the established white dwarf cases in detail, but will mention some of the interesting incidents that occurred in the course of their discovery.

There are, for instance, some cases where the spectrum is entirely devoid of lines, just continuous. One of these stars, No. 8247 in the zone of 70° northern declination of the Astrographic Catalogue, was assigned by Kuiper, on the basis of its peculiar spectrum, an effective surface temperature of 28,000°. Since the distance of this star had been determined, its intrinsic brightness could be derived. Realizing that the latter is pro-

portional to the square of the radius and the fourth power of the surface temperature, this relation was utilized to derive the value of the radius. It was found to be equal to *one half of the earth's radius,* making this star the smallest known. A direct determination of the mass was not possible, but from the theoretical relation between radius and mass derived by Chandrasekhar for degenerate gas spheres, the mass could be calculated and was found to amount to 2.8 solar masses. This amount of matter, then, is all packed in a sphere with only half the earth's radius. It can hardly be a surprise any more that the figure for the density assumes staggering dimensions. We find it to be 36 million times the density of water, weighing a mere 620 tons per cubic inch if at the surface of the earth. Incidentally, the force of gravity on the surface of the star is 3½ million times that on earth.

Of all white dwarfs, only three are near-by stars, situated within 16 light years of the sun. In fact, all the others are beyond 40 light years. If we assume that no more stars will be found within this limit, we can calculate the relative frequency of the white dwarf stars. The frequency of all stars in the neighborhood of the sun, that is, within 25 light years, is fairly well known from various methods of attack. If we adopt one of the more recent determinations, that by van Maanen, the white dwarfs are found to constitute about one per cent. of all stars. However, it seems likely that this estimate may be much too low; in fact, the white dwarfs may prove to be quite abundant. At any rate, whether of exceptional type or not, they will continue to occupy a first rank position among astrophysical problems.

Much research remains to be done, not only with regard to the white dwarfs as such, but also to their relation to other stars, notably the relatively dense nuclei of planetary nebulae and the "end-products" of the exploding novae. The spectral features in common between these stars and the white dwarfs would point to a possible relationship. Their densities, however, though of the highest among the "normal" stars, are no match for those of the extremely compressed white dwarfs.

Possibly further insight into the properties of super-dense matter may lead to a better understanding of the constitution of the more normal stars. If the problem of stellar evolution is to be solved, we must fit into its scheme not only these super-dense stars, but also the massive super-giants in highly diffuse states, the unstable configurations presented by the pulsating Cepheid variables, etc.

Perhaps the "gap" in luminosity between the normal intrinsically bright white stars and the faint white dwarfs may eventually be filled, depending on the outcome of extended spectral analyses and distance determinations. For this purpose we at the McCormick Observatory are determining the distances of all white stars which, on the basis of proper motion and apparent brightness, show a promise of being "intermediates."

The figure taken from Volume VIII of the Publications of the Leander McCormick Observatory will serve to illustrate this further. In this familiar Russell-Hertzsprung diagram, 1206 stars are plotted according to their spectral types and absolute magnitudes—as a measure of their luminosities—based on determinations of their parallaxes with the McCormick refractor.

At the first glance the diagram may appear as the cold, matter-of-fact statistics of 25 years of continuous parallax research. However, looking more intently, we shall read in it a vivid description of the variety of brilliance and color of a sidereal Broadway. At once conspicuous features attract our attention, the near equality in brightness of the most brilliant displays, the stars on the

"giant" branch, regardless of their color; the gradual dimming of the less assuming lights, the stars on the "Main Sequence," as we pass from the bluest, along orange and yellow to the reddest members; and last but not least the feeble, unjustly modest display of the white dwarfs, in splendid isolation.

It must be stated that Sirius B, among others, does not appear on the McCormick diagram, as its distance was not determined directly, though it is known accurately through measures of Sirius A. However, the inclusion of the omitted white dwarfs would not materially alter but would rather strengthen the position of this small group of B and A type stars of low luminosity.

From the evolutionary point of view it can be stated with certainty that the diagram as a whole represents a set of loci of equilibrium points, each point representing some particular stage in the process of stellar evolution. As to the course of travel there may well be a multitude of tracks on this emplacement. Presumably abundant will be the course of gradual changes of luminosity, color, mass, etc., along the same or parallel tracks. Then again we may have to deal with unruly bodies which would at times prefer to jump their tracks in order to proceed on others.

Valuable contributions to the interpretation of the Russell-Hertzsprung diagram in recent years have been made by Strömgren and others, through studies of the hydrogen content masses and radii of the stars.

As to the white dwarfs, the importance of observational work such as Kuiper's need hardly be emphasized, and no less that of those who, through equally painstaking research, provided the suspects, the relatively small group of stars of large proper motion. Discoveries of new white dwarfs, extended studies of their spectra and determination of their intrinsic brightnesses will serve not only to add to our knowledge of these objects, but also may throw new light on their relations to the other stars.

Then, also, there may come an announcement of the discovery of the first yellow or perhaps red "subdwarf," possibly cases of former white dwarfs well on their way to their ultimate fate, the "black" dwarf state of death of all super-dense matter.

These types of stars, however, are still brain-children of theorists, and to some degree products of wishful thinking and dabbling in speculation. Whether or not they are missing links in the evolutionary scheme and do exist in space, time only can tell.

HEREDITY AND THE LAWYER

By Dr. ALEXANDER S. WIENER

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In recent years, judges, juries and lawyers have become more receptive to the application of scientific knowledge for the solution of problems arising in courts of law. Still fresh in the minds of most American citizens is the Lindbergh kidnapping case, in which an expert on wood linked Bruno Hauptman with the crime by showing that the wood in the ladder used in the kidnapping had been taken from the floor of the attic in the Hauptman home. The Ruxton case in England, in which portions of the dismembered bodies of Mrs. Ruxton and her nurse-maid were successfully pieced together and identified, is another good example of the successful application of scientific methods in a criminal case.

Not infrequently courts of law are confronted with cases where a knowledge of genetics is of value. For instance, the decision of the court may depend on whether or not a particular individual is the child of a certain man and a certain woman. The most common examples are paternity proceedings, where the child has been born out of wedlock and the mother claims a particular man to be the father. In these cases, it is important to fix properly the responsibility for the support of the child, who might otherwise become a public charge. In divorce cases, the husband may assert his wife to be guilty of adultery, and as evidence of such adultery endeavor to prove that he can not possibly be the father of the child born during their marriage. In inheritance cases, impostors have put in claims by posing as long-lost heirs to the estate. The most notorious example in recent years of such an unsuccessful attempt is the Wendel case.

In the thirteenth century problems of blood relationship were claimed to be "solved" in Japan and China by the "blood-dropping test," in which drops of blood of the individuals being tested were allowed to fall into water simultaneously; if the drops came together the conclusion was that a relationship existed. As recently as 1929, a counterpart of this naïve test was invented by Zangemeister. In Zangemeister's test the sera of the child and the putative father were mixed and the mixture examined in a photometer for an increase in turbidity, the occurrence of which was supposed to be proof of paternity. A similar turbidity was supposed to appear in mixtures of the sera of husband and wife, but mixtures of sera of unrelated individuals were said to remain perfectly clear. Zangemeister stated that this supposed phenomenon was the result of the immunization of the mother and fetus in utero to the sperm of the father. This test and a similar one invented by Zangemeister for the diagnosis of pregnancy were "successful" only in his own hands, so they have been relegated to the same category as the tests used in Japan and China in olden times.

A more valid method of establishing familial relationship and at the same time among the most ancient is by demonstrating a facial resemblance of the child to its parents. This phenomenon is so common that it hardly requires discussion. The most outstanding example is the resemblance between a pair of *monovular* or so-called "identical" twins. Such twins result when a single ovum fertilized by a single sperm, instead of developing into a single individ-

ual, splits in half, and each half develops into a separate individual. On the other hand, *biovular*, or "fraternal" twins develop from entirely different fertilized eggs and therefore, aside from the fact that they are of equal age, are no more alike than ordinary brothers and sisters. Monovular twins are as much alike and no more different than the two sides of the body, so that it is difficult for strangers to tell one from the other. So great was the faith of the ancient Carthaginians in resemblance as a criterion for determining parentage that all children at the age of two months were examined by a special committee, and if the resemblance to the father was not great enough they were done away with.

In courts of law the resemblance between the child and its supposed parents has frequently been advanced as evidence of parentage. In the Wendel case the claimant to the estate pointed out the similarity between his own features and those of a bust of the deceased. Establishing parentage by resemblance has, however, many serious limitations. When the likeness is particularly striking, as in the case of identical twins, little doubt would seem possible, but as a rule the resemblance is not so strong. In ascertaining resemblances there is a strong subjective element, particularly with infants and young children whose features are not fully formed. Moreover, features will change as a result of age, diet, disease, injuries, etc., and in this way one can easily be misled. Two closely related individuals may appear entirely different; two homely parents can have beautiful children, and two beautiful parents can have homely children.[1]

On the other hand, two totally unrelated individuals may strikingly resemble each other, as in Mark Twain's novel, "The Prince and the Pauper," and there have been such instances reported in the daily press, involving prominent personalities. Resemblance is even more difficult to ascertain when comparison is made not between two living individuals but between two pictures or busts. For these reasons, many courts of law, such as those in New York State, do not permit the exhibition of the child to the jury for purposes of comparison with the putative father in cases of disputed parentage. Indeed, such a proceeding would merely serve to arouse the emotions of the jury and prejudice them against the defendant, rather than permit a sober unbiased appraisal of the situation.

The main cause for the difficulties entailed in applying resemblance as a mode of establishing parentage is that the features are the complex result of the many separate characteristics which enter into it, each of which has its own independent inheritance. A more scientific approach to the problem, and a more objective one, is through the use of so-called "unit characters."

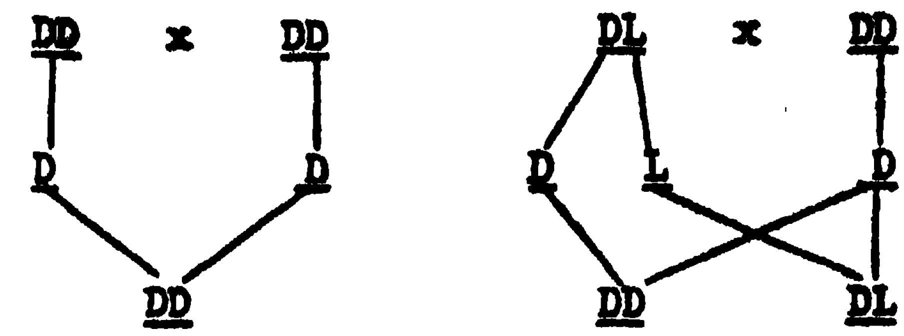
As Mendel first pointed out at the middle of the nineteenth century, such unit characters are transmitted by determiners now known as genes. As an example of a unit character let us consider the color of the eyes. For simplicity, eye colors can be classified as dark and light. These characters are inherited by means of a pair of allelic genes, which may be designated by the letters *d* and *l*, respectively, where *d* represents the gene for dark eyes, *l* the gene for light eyes. Since each individual has in his somatic cells two genes for each unit character, one from the father and the other from the mother, there are three genotypes possible with respect to the genes *d* and *l*, namely, *dd*, *ll* and *dl*. Obviously, individuals of genotype *dd* will have dark eyes and individuals of

[1] *Cf.* A. Scheinfeld, "You and Heredity," Chapter XXVIII. New York: F. A. Stokes Company. 1939.

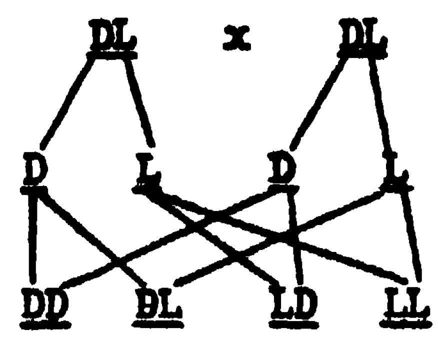
genotype *ll* will have light eyes. With regard to the individuals of genotype *dl*, Davenport has shown that the gene for dark eyes is dominant over the gene for light eyes, so that such individuals will have dark eyes.

With the aid of Davenport's theory of the inheritance of eye color it is possible to predict the colors of the children's eyes if those of the parents are known. There are three matings possible: (1) both parents dark-eyed, (2) one parent dark-eyed and the other light-eyed and (3) both parents light-eyed. Let us consider, for example, the matings where both parents have light eyes. In these cases both parents are of genotype *ll*, and as every germ cell contains one and only one gene from each allelic pair, all the germ cells of both parents will contain gene *l*. At fertilization, therefore, only zygotes[2] of genotype *ll* will be produced and all the children will have light eyes. The other matings are worked out in a similar way, but one must bear in mind that when a parent has dark eyes his or her genotype may be either *dd* or *dl*.

The results of Davenport's theory may be summarized as follows: (1) when one or both parents have dark eyes the children can have either dark or light eyes; (2) if both parents have light eyes none of the children can have dark eyes. The rule of practical importance is the second, since on this basis it would theoretically be possible to prove that a given individual is not the father of a certain child. If a woman has light eyes and her child dark eyes, then no man with light eyes could be its father; on the other hand, if the accused man in such a case had dark eyes, that would not necessarily prove that he was the father of the child, since a large percentage of individuals have dark eyes.

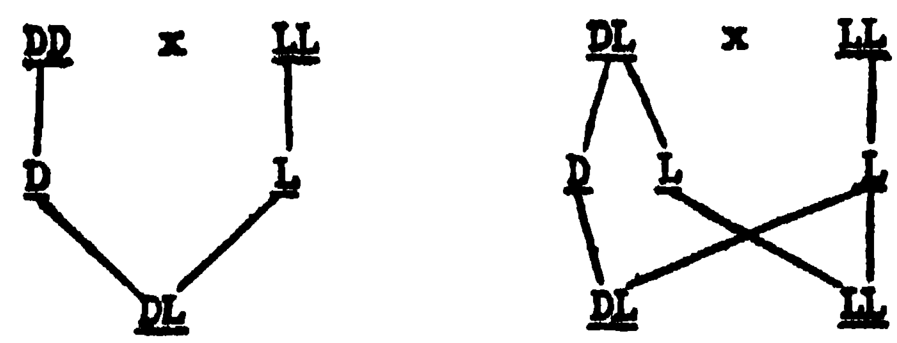


(100% dark-eyed children) (100% dark-eyed)



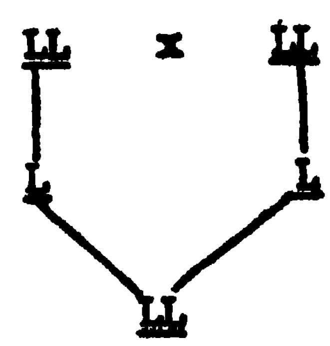
(75% dark-eyed) (25% light)

(a) Matings in which both parents have dark eyes.



(100% dark-eyed) (50% dark) (50% light)

(b) Matings in which one parent has dark eyes, the other light eyes.



(100% light-eyed)

(c) Matings in which both parents have light eyes.

INHERITANCE OF EYE COLOR IN MAN

GENOTYPES OF PARENTS ARE INDICATED BY LETTERS AT TOPS OF DIAGRAMS; THE GAMETES (GERM CELLS) BY LETTERS AT CENTERS AND THE GENOTYPES OF THE CHILDREN AT BOTTOMS.

Unfortunately, there are a number of serious obstacles to the reliable application of Davenport's theory of heredity of eye color in medico-legal cases. First of all, the simple classification of eye color as dark and light does not correspond with the real state of affairs. Actually, a rather large variety of colors and shades exist, such as brown, black, gray, hazel, blue and green; in albinos

[2] Fertilized ova.

the eyes may be pink. To allow for these possibilities it is necessary to postulate the existence not of a pair but of multiple allelic genes. Moreover, the dominance of the dark colors, brown and black, over the lighter colors, gray, blue and green, is not absolute, so that occasionally individuals of genotype *dl* may have light eyes instead of dark eyes. If two such light-eyed individuals intermarry they might have a dark-eyed child, thus upsetting the rules of hereditary transmission. Finally, the eye color does not remain constant throughout life. In newborn infants the eyes are usually blue or some other light color, but later on they may change to a darker color such as brown; moreover, one's eye color may change as a result of disease involving the iris, or in old age.

When we turn to other normal physical characters we encounter similar obstacles to their application in problems of parentage. For example, though there is no doubt that the type of ear-lobe, whether large and free or small and attached to the side of the head, is hereditary, the mechanism of transmission is not clear-cut, so that it is not possible to predict with absolute certainty what type or types of ear-lobes the children will have when those of the parents are known. The same may be said for the finger-prints, the use of which in paternity disputes has been advocated by certain investigators (Nurnberger, Bonnevie). It might seem that the finger-prints would furnish the ideal solution in problems of disputed parentage in view of their pronounced individuality. However, it appears that the mechanism of heredity of the finger-prints must be almost as complicated as the finger-prints themselves, and even to-day their heredity is not clearly understood. One limitation is that the finger-prints on the right and left hands of the same individual may be quite different (as are the finger-prints of identical twins), although such prints show a closer resemblance than the prints from unrelated individuals.

In fact, hardly any of the normal individual differences among human beings visible to the unaided eye have as perfectly simple an inheritance as that described by Mendel in his classic studies on the sweet pea. There are, however, individual differences among normal humans which are not visible to the naked eye, but are of a biochemical nature which exhibit a simple Mendelian inheritance. The most important of these characters are the blood groups, O, A, B and AB. The existence of individual differences in human blood was discovered by Landsteiner in 1900–01, who with Levine also discovered the so-called human blood types, M, N and MN, in 1928.

What blood group a person belongs to is determined by testing his red blood cells for two substances known as agglutinogens A and B, respectively. The chemical nature of these substances is not completely understood, though they seem to be related to polysaccharides, and no physiological function has been found that they perform. Their presence or absence in the blood is determined with the aid of two sera, one containing agglutinin anti-A, the other anti-B, which act on blood containing agglutinogens A and B, respectively. If the agglutinogen in question is present in the cells, the cells will clump together (or agglutinate) into large masses; if the agglutinogen is absent, no clumping of the cells occurs. If no agglutination occurs in either serum, the group is O; if clumping occurs only with the anti-A serum, the group is A; if clumping occurs only with the anti-B serum, the group is B; and if clumping occurs with both sera, the group is AB.[3]

[3] These reactions are the basis of the fatal sequelae which may result if blood of the improper group is administered in a blood transfusion.

As Bernstein has shown, the inheritance of the blood groups is determined by a series of allelic genes A, B and O, where genes A and B determine agglutinogens A and B, respectively, and are dominant over gene O.[4] Corresponding to the four blood groups, therefore, six genotypes are possible, as follows: Group O—genotype OO; group A—genotypes AA and AO; group B—genotypes BB and BO; group AB—genotype AB. It is a simple matter to ascertain what groups can occur in the children when the groups of the parents are known, in the manner outlined when discussing the inheritance of eye-color. Ten matings are possible, and these together with the children possible are given in Table 1.

TABLE 1
THE LANDSTEINER BLOOD GROUPS IN PARENTS AND CHILDREN

Groups of parents	Groups of children possible	Groups of children not possible
1. O × O	O	A, B, AB
2. O × A	O, A	B, AB
3. O × B	O, B	A, AB
4. A × A	O, A	B, AB
5. A × B	O, A, B, AB	—
6. B × B	O, B	A, AB
7. O × AB	A, B	O, AB
8. A × AB	A, B, AB	O
9. B × AB	A, B, AB	O
10. AB × AB	A, B, AB	O

For those interested primarily in the application of blood grouping in cases of disputed parentage, it is sufficient merely to remember the following two laws of inheritance: (1) Agglutinogen A or B can not appear in the blood of a child unless present in the blood of one or both parents. (2) A group AB parent can not have a group O child, and a group O parent can not have a group AB child.

To illustrate how this knowledge is applied, a case will be described in which a mixture of babies occurred in a Chicago hospital in 1930, the problem finally being solved by the blood grouping tests. Mr. and Mrs. B., on returning home from the hospital with their baby, noticed that it bore a label on its back with the name "W." They immediately hurried to the home of Mr. and Mrs. W. and it was found that the baby there had a label "B." on its back. The poor parents were in a quandary, not knowing whether they had taken their own babies home or the labels on the infants' backs were correct, and they sued the hospital for damages. The court ordered blood tests to be made and the findings were as follows:

Blood of:	*Group:*	*Blood of:*	*Group:*
Mr. B.	AB	Mr. W.	O
Mrs. B.	O	Mrs. W.	O
Baby "W."	O	Baby "B."	A

Since two parents of groups AB and O, respectively, can have only children of groups A and B, but not of group O or AB, it is evident that the baby with the label "W." on its back could not possibly be the child of Mr. and Mrs. B.; on the other hand, the baby labelled "B." could be their child. Moreover, since two group O parents can only have group O children, Mr. and Mrs. W. could not possibly be the parents of the baby labelled "B." but could be the parents of the other child. In this way the blood grouping tests solved the vexing problem and, by order of the court, the children were exchanged and restored to their own parents.

It is evident that with the aid of the blood tests it is possible to assert only that a given individual *can not be* the father of a given child in those instances where the groups do not conform with the laws of inheritance cited above. It is not possible to assert with certainty that a certain person *is* the parent of a given child, except where it is known that one out of a few individuals only could be the father, and all but one of these are excluded by the tests. When a man has been unjustly accused of the

[4] The heredity of the blood groups has been compared to that of the color of flowers and to that of the color of the eyes.

paternity of a given child, his innocence can be established with the aid of the blood groups in about one sixth of the cases. The number of such cases which can be solved was doubled by the discovery in 1928 by Landsteiner and Levine of two additional agglutinogens of human blood, designated by the letters M and N. These properties, which are entirely independent of the agglutinogens A and B, determine three types of blood, M, N and MN, and are transmitted with the aid of a pair of allelic genes, M and N. Corresponding to the types the following genotypes exist: type M—genotype MM; type N—genotype NN; type MN—genotype MN. On the basis of this theory, the inheritance of agglutinogens M and N is as given in Table 2. For use in the courtroom it is

TABLE 2

THE AGGLUTINOGENS M AND N IN PARENTS AND CHILDREN

Types of parents	Types of children possible	Types of children not possible
1. MN × MN	M, N, and MN	————
2. MN × N	N and MN	M
3. MN × M	M and MN	N
4. M × N	MN	M and N
5. N × N	N	M and MN
6. M × M	M	N and MN

sufficient to remember the following two laws: (1) The agglutinogens M and N can not appear in the blood of a child unless present in the blood of one or both parents. (2) A type M parent can not have a type N child and a type N parent can not have a type M child.

One case will be cited to illustrate the successful application of the agglutinogens M and N for solving a problem of disputed parentage. A woman sued her husband on account of non-support. He counter-claimed with a suit for annulment on the ground that he was not the father of his wife's child, but had been led to marry her by her false assertion that the child was the result of one of their clandestine meetings during her previous marriage. When the bloods were examined by the writer, no definite conclusions could be drawn from the tests for A and B. However, it was found that the woman in question belonged to type N and the child to type M, so that she could not be the mother of her supposed child. Further investigations revealed that the woman in the case had been married six times previously, and some old hospital records were found which revealed that she had had an operation some time previously which made it impossible for her to have had a child. Her contention was that the midline scar on her abdomen was the result of a Caesarean operation, though she could not produce the surgeon who was supposed to have performed the operation. Finally, the orphanage was located from which she had adopted the child which she used to perpetrate the fraud on her present husband.

Other cases in which blood grouping tests can be applied are inheritance disputes, divorce and rape cases, and kidnapping cases. Where litigation is anticipated in inheritance cases it may even be wise to take blood grouping tests on the deceased at the time of death. Of special interest are problems of paternity involving twins. If the twins are monovular they must have come from the same father, of course. In the case of fraternal twins, however, it is theoretically possible for each, while it has the same mother, to have a different father. This occurrence is known as superfecundation, and is scientifically possible though most difficult of proof. In 1934 Judge A. B. Tripp, sitting in Yankton, granted a divorce to a man on the grounds of infidelity. The man requested and obtained custody of the twin who looked like him, and the wife was left with the twin who looked like the neighbor. A more scientific conclusion would have been possible in this case had blood tests been made and it had been

shown that the claimant was not the father of one of the two twins. According to *Time* magazine,[5] American medical records of the last century contain reports of cases of two white girls, each of whom cohabited in rapid succession with a Negro and a white man. The result was that each bore twins, one of which was white, the other mulatto.

As mentioned above, a falsely accused man can be exonerated by means of the four blood groups in one sixth of the cases, and his chances have been increased to about 33 per cent. by the discovery of the properties M and N. The question may arise whether by the discovery of additional blood factors the percentage of successful cases can be raised to 100 per cent. Theoretically this ideal can be approached but not reached, since with each new factor that is tried there is overlapping with the older blood tests, some men being excluded by more than one of the blood tests. It might be mentioned that additional properties in human blood besides A, B, M and N have been discovered which can be used in problems of disputed parentage, but they have not been studied enough to warrant their use in the courtroom at the present time. Where one is asked to offer a private opinion as to paternity their use might be permissible, if the required reagents are available. The more important of these factors are the agglutinogens A_1 and A_2 (varieties of A agglutinogen), the agglutinogen Rh and agglutinogen P. In addition, people of groups A, B and AB may secrete group specific substances in their saliva, and the capacity to secrete them is hereditary. While morphological traits such as eye color, dimples in the chin, hair color, etc., do not exhibit as clear-cut an inheritance, in private consultations they may be used for the purpose of arriving at an opinion, though not an absolute decision, as to the paternity of a child, in cases where the result of the blood tests are inconclusive.

Aside from the normal individual differences there are numerous abnormal anatomical and physiological anomalies which are hereditary, such as polydactylism, claw hand, hemophilia, albinism, etc. These abnormal traits are mostly inherited as simple unit characters in accordance with the Mendelian laws, and therefore can be used in paternity proceedings should they occur in parents and children. In fact, because of the rarity of such anomalies, their simultaneous presence in the putative father and child may be taken as strong circumstantial evidence that the man in question actually is the father of the child. Mohr cites a case in which the presence of brachyphalangy (short fingers) was the basis of a court's decision that the man in question was actually the father.

Until recently one of the major impediments to the more general acceptance of the blood grouping tests in the courts of this country has been the lack of suitable legislation giving the courts power to compel individuals in such proceedings to submit to blood examinations. Suitable laws have, however, been passed in New York, Wisconsin, New Jersey, Ohio and Maine, and similar legislation is pending in other states. Another difficulty is the lack of a sufficient number of qualified individuals in each state to carry out such examinations. The conducting of a blood grouping examination requires rather highly specialized knowledge, and erroneous reports have been rendered where inexperienced individuals were permitted to carry out the tests.[6] But bloods can be drawn in one locality and shipped through the mails to individuals qualified to carry out the examination. In one such case the

[5] *Time*, Jan. 8, 1934.

[6] *Cf.* Report of the Committee on Medico-legal Blood Grouping Tests, *Jour. Amer. Med. Assoc.*, 108: 2138, 2115, 1937.

writer in New York received bloods of a mother and child 24 hours after the birth of a baby in a hospital in Colorado, the man's blood being taken in New York. Since the blood had been shipped by air mail and packed in ice, the cells were practically fresh when received, despite the great distance involved, and the examinations were conducted with no greater difficulty than if the individuals had all put in a personal appearance.

In conclusion the writer would like to point to a recent decision of the United States Court of Appeals for the District of Columbia. In this case, involving the paternity of a baby born in wedlock, the court issued an order directing a man, wife and child to submit to blood grouping tests, and this order was affirmed by the Court of Appeals, which accepted as established the scientific value of the blood tests. An editorial which appeared in a recent issue[7] of the *Journal* of the American Medical Association, commenting favorably on this decision, closed with the following sentence: "Granting the right of the court to compel submission to blood grouping tests, either by authority of a special law . . . or under a more embracive statute authorizing the court to compel submission to physical examination without specifically mentioning blood grouping tests, as was the situation in the recent District of Columbia case, there would seem to be no justification for further hesitancy on the part of the courts to accept as scientifically sound the results of blood grouping tests to the extent that they disprove the possibility of paternity."

[7] *Jour. Amer. Med. Assoc.*, 115: 306, July 27, 1940.

A PHYSICIST'S VIEW OF ETHICS

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Professor Conklin, in his article "Does Science Afford a Basis for Ethics?" in the October, 1939, issue of The Scientific Monthly, showed that science does afford a basis for ethics but did not go ahead to outline, as I shall try to do, a theory which can serve as the skeleton of a science of ethics. Conklin is right in saying that ethics is natural in origin and has undergone an evolution from simple to complex. Further, such a natural development of ethics is more hopeful than any supernatural development could be. To a limited extent I agree that "As one goes up through higher and higher social grades one finds that altruism reaches farther and takes in more people, until with some persons it includes the whole human race"; but I think that Conklin is using the word altruism a bit loosely here. It seems better to say that as the minds of persons become more highly developed their interest in, and sympathy for, others broadens, but this interest and sympathy is never really altruistic.

Ethics becomes more understandable to me after making an analysis of its supposed base: altruism. When one studies the evolution of ethics in particular, and human behavior in general, it seems clear that selfishness is universal, obvious in many cases, disguised in others, unavoidable in all. Selfishness is a good thing simply because it is necessary for the preservation and growth of living things. Many will say that I am "unethical" in acknowledging the pursuit of pleasure or happiness as my sole aim in life, but they misuse the

word. They would be speaking more accurately if they said that a hedonistic code of ethics conflicts with their codes of ethics.

Pleasure is one of those things which are too fundamental to define in terms of simpler things; one can only define it by exemplification. In general, one may say that the exercise of any normal function of the human body produces pleasure. That statement is perhaps as much a definition of normal function as of pleasure. Eating, drinking, resting and sexual intercourse are examples of obviously normal bodily functions that are normally pleasurable. If a person does not enjoy such elementary actions in reasonable amounts, something is wrong with him or her, physiologically or psychologically. What other experiences one considers pleasant is dependent on one's mental development, training and habits, and in some cases these experiences may be fantastic and apparently unexplainable. Thought or consciousness may be considered to be the highest human function or bodily process; its performance, accordingly, should give the highest pleasure. The fact that many people say that "thinking is the hardest work to do" indicates how poorly developed this function is in them. One who does not enjoy thinking has not done much of it, for thinking is like a game which one enjoys more, the more practice one has had and the better one can play. Thinking is, moreover, a pleasure which, like eating, may be indulged in unwisely. Overthinking on a useless subject, or daydreaming, can waste time just as overeating can cause indigestion.

One may say that the highest type of thinking is that type called creative, although all thinking is to some extent creative. Even a student carefully following the train of thought of the author of a text-book is creating anew for himself the ideas which may have been possessed by millions before but are yet fresh and unexplored to him. There are three requirements for creative thinking: First, the mind must have ideas to work with; these require experience and reflection to form. Second, the mind must have imagination, the ability to put these ideas together in new combinations. Third, the mind must have the ability to recognize the value in certain of these combinations which may appear to have been formed as if by accident without conscious desire or direction. All three of these phases of creative thinking have evolved naturally from lower forms of nervous and mental activity. It may then be expected that the exercise of imagination will bring pleasure. This is found to be true; indeed, for some people the highest type of pleasure is obtained from imaginative thinking. For instance, the use of imagination in science, primarily in the construction of theories, is an essentially selfish act performed to gain pleasure, as is every other mental act. This is often indirectly admitted by the scientists themselves when they speak of the "beauty" and "elegance" of their theories. To one able to appreciate it, the beauty of a far-reaching theory may be as great as that of the best painting or sculpture. The pleasure derived from the creation of the theory may also be as great as that enjoyed by the painter or sculptor or musician, and is of the same intellectual or mental type.

Even the mass of unscientific people, who have never consciously created a scientific theory, and who think that "facts" are superior to "theory," do a great deal of theoretical thinking, and get pleasure from it, without realizing the nature of what they are doing. The things that are called facts by those persons who claim to be interested only in "practical facts" always involve some theory of the world which is so commonly accepted that its theoretical na-

ture is unnoticed. The common idea of an antithesis between theory and facts, or between theory and practice, is an unfortunate misconception. The most practical and labor-saving thing in the world is a good theory, one that has been verified and found to work. As for facts or knowledge, we have only a set of sense impressions which is organized to a limited extent by means of ideas and theories of varying degrees of simplicity and clearness. The thing that, alone, makes sense impressions have meaning is that purest and most valuable of all fictions, the physical world, which we postulate as the cause of the perceptions. Without this fiction our perceptions are meaningless; in fact, we would not even have what most people, including most philosophers and psychologists, call crude sense impressions, but only have vague feelings of comfort or discomfort. For example, one can not recognize that the sensation produced by breathing ammonia vapor is a smell, not merely an unpleasant feeling of unknown origin, without having had previous experience with ammonia and the sense of smell, not even without something of a theory of the structure of the universe and of mankind's place in it.

Imagination and creativeness are usually thought to be characteristics of artists and not of scientists, but this is an error. Art may be defined broadly as a human activity whose purpose is the attainment of pleasure by the artist and the fulfilment of his emotional desires. The true scientist, who is not a mere technician or investigator of details, is an artist in this general sense. Imagination has been an important feature of the work of the greatest scientists. Newton's law of gravitation is as much a work of creative genius as any of Beethoven's symphonies are, although it was put forth as a universal law, and has had abundant verification as such. As Havelock Ellis says in his chapter on "The Art of Thinking" in "The Dance of Life":

> Science is not the accumulation of knowledge in the sense of piling up isolated facts, but the active organization of knowledge, . . . this task is impossible without the widest range of vision and most restless fertility of imagination.

There is a close connection between ethics and esthetics. Esthetics, usually defined as the study of beauty, is largely a study of pleasure, since beauty is that quality which we attribute to an object as the cause of the emotion of pleasure the object gives us. Birkhoff has developed a theory of esthetic measure which seems to be a promising beginning in this field. His theory assumes that esthetic value is associated with order or the degree of "unity-in-multiplicity." He limits himself to "formal elements of order, in contradistinction to connotative elements of order," but the reasons for pleasure being caused by perceiving elements of order are the same in both cases. The connotative elements can not be taken account of by a formalistic theory but are very important. The fact that we all find delight in familiar and habitual things, though too frequent repetition becomes irritating, has a physical basis that would be difficult to explain in detail. We also delight in the new if it is not completely new, and if there are some familiar features recognizable. The pleasure we feel in the recognition of old elements in new combinations may be considered as pleasure in performing the normal function of thinking, for the recognition of similarities is one of the most important and most fundamental types of thinking.

A person may be said to be impelled in the direction of maximum pleasure in a way analogous to the acceleration of a free mass in the direction of the maximum gradient of the gravitational potential field. Of course the psycholog-

ical problem is not as simple as the analogous mechanical one. While all masses placed at the same point in a gravitational field will be accelerated in the same direction, different persons in the same situation can act in different ways. The explanation in terms of the principle of maximum pleasure is that different people, because of their differing natures, give different values to the pleasures to be derived from the various modes of action possible in a given situation. In this way the maximum pleasure is obtained in different directions by different persons. The gravitational case would be similar to the psychological one if different masses were polarized in some way such that the components of the gravitational field were given different relative weights. A like case is that of an electron in a magnetic field. Electrons moving in different directions at the same point of the field will experience forces acting in different directions. Here the difference in the directions of motion of electrons corresponds to the difference in the psychological natures of individuals. The physical case is still much simpler than the psychological one, since the electrons vary only in velocity, a quantity having three independent components, while human beings vary in innumerable distinct ways. A person for whom the greatest pleasure is found in association with people and in the feeling of power that comes from being a person in authority will attempt to become a leader in business, politics or other fields. One for whom the greatest pleasure is the self-satisfaction that comes from doing apparently unselfish things will become a charitable person. And one, such as I think I am, for whom the greatest pleasure is found in learning and in understanding will naturally become a student and a scientist.

Although altruism, strictly speaking, does not exist, this concept is a convenient fiction which is often useful in the concise description of human actions. Actions which are apparently altruistic or unselfish, and usually pass for altruism, have always appeared to me, on close study, to be efforts to satisfy some obscure desire for self-approval. The person in question is often unaware of the nature of his feeling of self-satisfaction, and he sincerely believes that he is doing an unselfish act. This ability to obtain pleasure from a superficially unselfish act, which is usually the result of religious training that assumed the existence of genuine altruism, is one of the things that enable fundamentally selfish people to live together more or less harmoniously in a society where immediate selfish interests often conflict. On a higher, as least more abstract, level is an understanding of the fact that to obtain maximum pleasure from civilized life it is necessary to curb one's immediate selfish interests in favor of higher selfish interests which advance the welfare of society, and incidentally advance one's own welfare. The hope of the world for a more perfect civilization lies more in the growth of enlightened selfishness than in a Kingdom of God or in any other hazy idea of a prophet.

What, then, is good and evil, if unselfishness is not good and selfishness is not evil? We can not define absolute and universal good and evil; we can only define individual and relative goods and evils, each completely valid only for one person at one time, although with some modification it may serve at another time or place. That which is good for me now, for instance, is that which helps me to grow, physically and mentally. In general, the same is true for others, though the details of what is good for them will not be the same as for me. In so far as I have developed beyond a mere animal, my needs will be broader and my idea of good will be higher than the satisfaction of animal instincts. Is

it higher because I have a greater range of experience and desires? Or because I realize that to live happily in an organized society I must consider the sometimes conflicting needs of others, and must restrain some self-centered desires in order to satisfy desires for social pleasures? Or because I can see forward a little into the future, and can restrain a desire for immediate pleasure in order to obtain a greater future happiness? We can go no farther than this, I think, in trying to set an absolute standard of good and evil. Each one of us has a set of more or less well-defined ideas of good and evil. It is questionable whether a single concept of goodness can be formed consistent with all these ideas, or even representative of a common fundamental notion in them. The greatest good of the greatest number is commonly considered a more admirable ideal than personal happiness. But why? Is there anything to the welfare of society beyond the welfare of its members? The state itself can not enjoy anything, not even the happiness of its citizens. I disagree violently with those nationalist orators who imply that the state or nation has a life or consciousness of its own superior to that of the individuals who compose it.

There is no religion; there are only religions. By that I mean that it is impossible to frame a single definition of religion consistent with all the religions that have been developed in the history of the human race, since that which has been called religion has varied too much with person, time and place. However, most religions fall into two classes which overlap somewhat. First there are those involving a belief in a divine Being or Beings having material existence and supernatural powers. These largely consist of a primitive cosmology colored with such emotions as reverence, awe and guilt. The priests, prophets and medicine men who created the primitive religions were the scientists of their day, although the cosmologies contained in their religions are incompatible with the results of modern physics and astronomy. In fact, a supernaturalism which postulates the existence of a divine being not subject to the laws governing the rest of the world is based on an essentially unscientific attitude toward the world. A supernatural religion thus conflicts with science, even though its adherents try to avoid the conflict by saying that religion deals only with spiritual things while science deals with material things. Second there are those religions in which the God has become an abstraction without personal existence, and in which emphasis is laid on the relations of people to the others among whom they live. Some persons would call this type of religion a code of ethics, and reserve the name religion for the first class. Even religions of this second class are in conflict with science to the extent that they are based on unscientific ideas of sin and salvation.

A religion concerned only with spiritual things, such as many people claim to have, is impossible, or at least futile. Exponents of such a religion do not clearly realize what they mean by "spiritual." They imagine that human thoughts and desires are purely spiritual processes, processes that have no physical basis, because they are not aware of the physical mechanism underlying mental processes. Although no one knows the details of the physical basis of thinking, the absurdity of a belief that there is no such basis should be apparent to any one who considers the fact that if a brain is rendered inactive or damaged by drugs, accident or other physical means, the spirit or mind associated with it is invariably destroyed or greatly changed. If physical acts are really negligible to a religion, and only spiritual things are important,

then the religion becomes useless and academic, concerned only with unobservable things. Actually, religionists are always much concerned with human actions, which are physical phenomena if nothing else.

Parallel with the evolution of religions has been the evolution of ideas of God, beginning with material and personal gods possessing all the human desires and emotions of their worshippers, and progressing up to supposedly immaterial beings having none of the qualities of which their human creators were ashamed, yet still retaining the ability to know and plan and act as human beings do. The final stage in the transformation of the idea of God under the influence of science is a supreme world-spirit, immaterial and spiritual in nature, without power to act directly on the physical world. The existence of such a supernatural being is a possibility that can not be disproved; but it is meaningless and useless, since, by definition, it can never be observed. I know of no higher power than human intelligence, which has created all religions and ideas of God.

The soul, as usually imagined, is as supernatural as God and as hard for a true physicist to believe in. While I do not think that I am merely a haphazard collection of lifeless molecules, whatever I am, or my mind is, more than that clearly seems to be the result of the combination and organization of molecules. This result of combination is not matter in the ordinary sense of something having mass, but it is material in the sense that it can produce physical effects, and it is affected by physical conditions in the body. The fact that neither I nor any one else yet knows how consciousness results from the combination of molecules into cells and tissues is not a valid argument that it can not so result, or even that we can never know how.

An important role in many religions is played by the concept of sin. This is a fiction whose utility is limited by its being based on a belief in standards of good and evil that are thought to be divinely ordained and absolute, but are neither divine nor absolute, being traditional conclusions from old and very imperfect theories of human motivation and behavior. While I know of no theology in which ignorance is a sin, all the so-called sinful acts I have observed have been merely the result of ignorance or limited understanding. Even a criminal act performed under the influence of violent emotions is the result of the inadequacy of a mind, because of incomplete development, for performing its natural function of directing the body with which it is connected.

Acceptance of the ideas of sin and guilt requires a belief in a free soul with a complete knowledge of good and evil, and with the power to choose between them and either resist or yield to temptations to sin. Since I have rejected the usual ideas of the soul and sin it may be expected that I also reject the idea of "free will." This is true as far as ultimate belief in its existence is concerned, but the concept of a free will is a very useful one which need not be abandoned merely because it is false. Though usually based on a mistaken idea, free will is one of our most valuable fictions, one that is useful for the concise description of the process by which we make the multitude of decisions necessary in everyday life. Nearly the same idea is expressed by Planck in "The Philosophy of Physics": "Our consciousness . . . assures us that free will is supreme. Yet . . . we might say that looked at from outside (objectively) the will is causally determined, and that looked at from inside (subjectively) it is free." The more one's decisions are made by a free will which is the result of rational thought and of clear ideas of one's desires and of the consequences of one's

actions, rather than by an emotional free will, the more wise and intelligent one can claim to be and the happier one should succeed in being.

That every human action is a physical phenomenon determined by present and, indirectly, by past physical conditions is a conclusion that becomes more and more certain as one studies the structure of the human body and its behavior under varying conditions as a problem in physics. Here I am using physics in the general sense, the science of matter and energy and their transformations, to include all natural sciences such as chemistry and biology. Determinism seems unquestionable, and the existence of a free will, an immaterial soul or spirit which can make decisions independent of physical conditions, seems impossible when one studies the process of making decisions and attempts to analyze some typical elementary choices, and finds that apparently the choices depend on present conditions and past history. In my own case, the only one of which I have full and immediate knowledge, I have many times made as impersonal and as scientific an analysis as possible of my choices. Each time I was forced to the conclusion that the decision was determined by the situation I faced, and by my condition at the time, which condition was the result of previous experience. When I have tried to find out why I made a particular choice I have been able to see memories of past experiences which inclined me one way or the other, usually some each way, so that the decision was the result of conflicting forces, with the strongest finally winning out. By "forces" I do not mean the usual mechanical forces of physics but analogous fictions which, loosely speaking, seem to cause psychological phenomena in the same way that mechanical forces seem to cause mechanical phenomena.

To describe one of even the simplest of these forces in terms of the structure and connections of the nerve cells which produce the psychological phenomena would be very difficult. It would be practically impossible to describe the force in terms of the ultimate atomic structure of the body cells by means of some fundamental physical law such as Dirac's wave equation for the electron, generalized to apply to all other fundamental particles such as protons and neutrons. Yet I have faith that such an ultimate physical explanation is possible in principle, and is merely too complicated to carry out at present. The word faith is appropriate here since my belief in the possibility of ultimate detailed explanation lacks proof by actual performance, although it is upheld by increasingly detailed explanations that have been carried out. Faith, I would say, is belief in something unproven or unprovable that gives the believer pleasure. Beliefs in God, the soul and immortality are good examples of common faiths. Though I do not possess these faiths, I do have others, and do not mean to imply that faith is to be avoided entirely. For instance, one of my faiths is the fundamental belief of the physical scientist that the universe is orderly and understandable. Although this can never be completely proven, it is made plausible by the fact that many events and processes in nature have been found to be orderly and understandable, and it gives me great pleasure to believe it, the pleasure of the anticipation of the knowledge and power to be gained by studying the universe. In the same way, contemplation of the possibility of explaining all physical phenomena, even those amazingly complex ones called vital phenomena, by means of a single unified theory gives me a wonderfully pleasant feeling of the anticipation of power.

The problem of free will and choice becomes clearer if one approaches it sci-

entifically, trying to find the best explanation for a typical occurrence such as two persons meeting with the same situation, or situations which are practically identical as far as essential conditions are concerned, but reacting differently. Three types of explanation may be offered: First, the choice of reaction is absolutely unpredictable, so that no amount of knowledge of the situation or of the people would make it possible to predict the outcome. Second, the choice is determined by the free will or arbitrary choice of the persons involved. Third, the choice is determined by the physical conditions characteristic of the situation, and by the relation of these conditions to the physical structure of the person meeting the situation, which structure is the result of previous physical conditions. In more familiar terms, the choice is determined by the character of the person and the way the situation looks to him in the light of his past experience. The first, which hardly deserves the name explanation, denies without reason the applicability of science to human actions. The second is quite simple and does not obviously conflict with a scientific study of human behavior, but requires the observed phenomena constituting human actions to be separated from all other observed phenomena, and to be treated by an entirely different method which is rendered unsatisfactory by the admission of an unmeasurable factor that is observable only by means of effects produced without apparent relation to any past or present circumstance.

Some people who have faith in this second way of explaining a choice between alternative courses of action, but do not realize the full implications of such an attitude, have tried to rationalize it, and give themselves an opening to bring in free will, by seizing on the Heisenberg principle of uncertainty. They do not know what kind of uncertainty the principle deals with, yet they imply that even the physicist has given up determinism, apparently because uncertainty sounds as if it is incompatible with determinism. Heisenberg's principle does not conflict with a deterministic view of physics. It simply states that conjugate dynamical variables can not be measured simultaneously with unlimited precision. This bars the possibility of measuring the exact present condition of the universe, and then calculating its future conditions from the results of the measurements, even if the rules of calculation were known. But it does not deny a causal connection between the present and future. The Heisenberg principle is merely a precise statement of the observed fact that there is an unavoidable interaction between the observing apparatus and the object observed.

Probably the best example of an elementary process to which the uncertainty principle applies is the collision of an electron with a photon, called a Compton collision. Many such collisions have been observed in cloud chambers; in every thoroughly investigated case, energy and momentum were found to be conserved within the limits of accuracy of observation. Nothing is more typical of deterministic law than the laws of the conservation of momentum and energy. These laws relate fundamental physical properties of a system at one time to those at another time in the simplest possible way, by the relation of equality.

Though it is extremely important in individual quantum mechanical processes, the uncertainty principle becomes unimportant in the consideration of processes involving large numbers of atoms, as most bodily processes do. When large numbers are involved statistical laws apply with great accuracy. The small discrepancies between the re-

sults of observation and the predictions of statistical law leave little room for freedom of choice.

Closely related to free will is another useful fiction—self-control. Obviously a man can not really control himself any more than he can lift himself by his bootstraps. The idea is logically self-contradictory, but it often furnishes a convenient abbreviated way of describing an important psychological phenomenon. The common expression, "a struggle between higher and lower selves," is somewhat more accurate than self-control, but it assumes that higher and lower are absolutely defined, and it is oversimplified in that it neglects the fact that the splitting into two selves takes place in different ways on different issues. The exercise of self-control in the usual situation requiring a decision is more accurately described as follows: A man having a complex mental nature resulting from years of development and experience is confronted with a situation in which he sees two fairly distinct alternative courses to pursue. Some parts of his mind—psychological forces or whatever you wish to call them—tend to produce the choice of one of the alternatives, while other parts of the same mind tend the other way. In the case of a situation involving a moral issue, one of the courses is called yielding to temptation. The other is called resisting temptation, and the person choosing it is said to have used self-control. The psychological mechanism operating is the same in a case involving no moral issue, say the choice of the color of a hat, as in a case with a moral issue, although the strength of the conflicting forces may be much less. The choice that is made in any particular case depends, exactly as one should expect, both upon the nature of the man and of the situation in which he finds himself.

The development of self-control is then nothing but mental development and training which strengthens that side of the mind that tends in the general direction of resisting temptation. Though the faculty of self-control is one of our highest faculties, ranking with understanding and intelligence, its development by a long process of adaptation to environment is an essentially selfish process, as adaptation always is. It is generally considered that a well-developed faculty of self-control is necessary for a well-balanced mind. With this I agree, though I do not believe in self-control as most people conceive of it. I try to use as much self-control as possible, because I believe that I will enjoy life better and on a higher level if I can be as much as possible conscious of what I am doing, and for what purposes I am doing it, and choose my course of action with regard for others and for the future, rather than let habit and thoughtless emotion be my guide. This is not to imply that emotion is to be eliminated in favor of reason. Though we may try to live *by* reason, it is always emotion that we live *for*. Reasoning should be used to distinguish between good and bad emotions, between those, on one hand, that are short-sighted or low or poorly developed and those, on the other hand, that are far-sighted or high or well developed and that do not conflict with the happiness of others. Reason is the means; emotion is the end.

The concept of self-control may be somewhat clarified by comparing it with devices for controlling physical quantities such as temperature or electrical potential. There are three parts essential to a controlling device: First, a standard to which the variable can be compared, directly or indirectly; second, a means for detecting deviations of the variable from the standard; third, a means for correcting the deviations, which is actuated by the detecting means. Self-control of conduct requires three similar

things: First, the existence of an idea of a standard of conduct or of the particular phase of conduct to be controlled; second, the ability to perceive deviations of conduct from the standard; third, the ability to make corrective changes in conduct in accordance with the perceived deviations.

I do not think that I have proved anything in the foregoing paragraphs, chiefly because proof, as most people conceive of it, is impossible. Matters of objective fact have their accuracy limited by the errors of measurement, while a conclusion involving an abstract idea has its certainty limited by the limited clarity of conception of the ideas involved. To prove an abstract theorem to another, one can only indicate to him the processes by which one became convinced of its truth, and hope that he will see the truth. Whether or not he does see it, or thinks he sees it, will depend on many factors in his previous experience as well as on the absolute truth one attributes to the theorem. My feeling is that no truth exists in the conclusion of a theorem that does not exist implicitly in the definitions of the ideas involved. When I derive a proof I am only completing, by exploring their implications, the definitions of the ideas with which I started. I see no self-evident truth in axioms or postulates. They are merely disguised definitions which describe properties of the entities we have invented. Though there is no absolute standard of truth any more than there is an absolute standard of good and evil, there are two types of relative truth that can be recognized. One is internal self-consistency, such as a physical theory or a branch of mathematics may possess. The other is external consistency, such as the agreement of the predictions from a theory with the results of observation. A critical analysis thus seems to leave nothing of truth except lack of contradiction, yet the concept of truth is one of our noblest and most useful fictions, one that we could hardly dispense with. A theorem may then be said to be true if its conclusion is consistent with and logically following from its premises. In any particular case, this consistency and logical connection must be judged according to the personal standards of the person desiring to know whether the theorem is true or not. Though in many cases fairly general agreement can be reached as to what is true or what is just, in the end every man's truth is his own as is every man's justice.

Although this article was written partly in answer to that of Professor Conklin, I think that I have written in the same spirit as he in tracing the natural development of the highest types of thinking, including ethical thought, from simple origins. In agreement with my general thesis I may add that I consider the writing of this essay a selfish act on my part. I have obtained pleasure from it already and hope to obtain more from it in the future.

THE TROPICAL PLANTATION SYSTEM

By Dr. LEO WAIBEL
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THE plantation system is a form of agriculture in the tropics of great economic, social and political interest. In order to characterize this form of economy, we must answer three questions: What are plantations? What is their geographical distribution? What are the origins of the plantation system?

A plantation is not only an agricultural undertaking; it is also an industrial enterprise. It not only produces agricultural products; it also prepares them and makes them fit for transportation. This it must do, for it does not produce for its own needs, as does the native, but for the market and especially for the market of the temperate zones. These markets, however, are remote from the tropics, and, moreover, in order to reach them the ships have to pass through the hot, humid tropical latitudes.

In regard to the distribution of the plantation system, we note that it is found only in the tropics and the subtropics; they have long and in parts uninterrupted growing periods for vegetation, during which they produce certain valuable agricultural products that are lacking in the temperate zones. A great demand for these products, however, does not lead necessarily to the plantation system. In the Asiatic tropics, for example, spices have been produced for centuries by native peasants and have been taken by foreign traders (Chinese and Arabs) to the markets of the Far East and of the Occident. And to-day other products, such as cotton, kapok and copra, are produced either exclusively or preponderantly by the natives of the Netherlands East Indies for foreign markets. These products, which do not require difficult preparation and which can be easily transported, do not require the plantation system for their successful production.

On the other hand, the natives of the Netherlands East Indies produce only a scant one per cent. of the exported *sugar,* although they grow sugar-cane for their own needs. They use, however, either the fresh sap of the cane or make a brown, sirup-like mass which can not be transported but must be consumed on the spot. The natives are not capable of producing solid brown or white sugar, for to do this they would need, besides the sugar-cane, capital for constructing costly special sugar mills and they would have to have highly scientific and technical knowledge to operate them.

The plantation system, therefore, is found only in the tropics because it is there that crops are grown that require not only much unskilled labor but also highly technical knowledge and last investments in processing plants and equipment to prepare the products for shipment to distant markets. The result is that the natives must fit into a strange industrial order.

This industrialization is especially necessary in the cultivation of sugar-cane (and of sugar-beet in the temperate zones), because the easily perishable juice must be transformed into a product of stone-like hardness, the sweet salt, as the natives say. Other tropical plants—such as coffee, cocoa, tea, cinchona, cotton, sisal and rubber—require similar industrial processes, especially when a product of high value is to be produced. Industrialization, so unsuited by its very nature to the agriculture of the temperate zones, is therefore the most important characteristic of the plantation system.

Division of labor and a one-crop

economy go hand in hand with agricultural industrialization. It is well known that most plantations raise only one crop, such as sugar-cane or coffee or sisal, because each of these products requires its own special machinery. Rotation of crops is, therefore, impossible even in the growing of annual plants. As a consequence the soils are rapidly exhausted and new ones have to be continually prepared for cultivation.

This very one-sided economic system, which we call monoculture, results in great instability and a sensitivity to crises. Climatic changes, plant diseases, political troubles, new technical inventions and above all the market prices interfere gravely with the life of a plantation. It is thus understandable that some plantation areas have changed their products and their mechanical installations at frequent intervals. In the nineteenth century Ceylon, for example, produced successively cinnamon, coffee, cinchona, tea and rubber. Similar changes took place at the end of the eighteenth and at the beginning of the nineteenth century in the West Indies.

The same unrest and instability are manifested in the migration of plantation products. It is sufficient to call to mind the spread of coffee culture from Abyssinia to Arabia and southeast Asia, and then to the New World, where there was considerable shifting of coffee cultivation within the American tropics, and finally to the recent completion of the circle back in Africa.

Since the installation of expensive machines pays only if production is on a large scale, it follows that the plantations are almost always large estates of several hundred to several thousand acres. These large areas require, as do the associated factories, a great number of laborers. The labor problem is thus of paramount importance to the plantations, and this demand for plantation laborers was fundamentally responsible for the former Negro slave trade, as well as for to-day's great labor migration within the Asiatic tropics. Finally, the management of the fields and factories, and the sale of the products as well, must be in the hands of trained specialists. Since as a rule natives lack training and experience, it is generally true that only Europeans (in the cultural sense of that word) are fitted to be managers of plantation enterprises.

A plantation is, therefore, a large agricultural and industrial enterprise, managed as a rule by Europeans, which, at great expense of labor and capital, raises highly valuable agricultural products for the world market.

Turning to the question of the origin of this very special type of economy, it is not surprising to learn that it is closely connected with the fabrication of solid white sugar. Karl Ritter, the great German geographer, reached this conclusion a century ago, but his results have been forgotten even by German geographers. According to this famous scholar, the refining of sugar was invented in the seventh or eighth century A.D. in the Persian province of Chusistan (in the lower course of the Tigris and Euphrates Rivers), where European-Oriental science came into direct contact with the production of tropical sugar-cane. From the beginning sugar refining has gone hand in hand with the plantation system, and both have had a spectacular migration around the earth within the tropical and subtropical zones.

The Arabs laid out sugar plantations in the Mediterranean area, from them the Venetians and Genoese learned the science and the art of making sugar, and from them, in turn, the Spaniards and Portuguese. The two last nations carried the oriental type of agriculture and the Asiatic plant to the West African islands of Madeira and the Canaries, and from here it was taken to the tropics, and found its first classic tropical develop-

ment, in the closing years of the fifteenth century, on the small Portuguese island of Saint Thomé, in the inner Gulf of Guinea. In 1492, when Columbus started on his great discoveries, the sugar plantation system was well established on this island.

But these small West African islands soon lost their significance as sugar-producing centers when sugar-cane cultivation, together with the plantation system, was extended to the New World: to Santo Domingo in 1519 and to Brazil in 1531. Here much larger areas suitable for sugar-cane cultivation were available, and, in addition, the cane did not have to be irrigated, as it did in Madeira, the Canaries and the Mediterranean areas. Therefore, in spite of the greater distance of America from the European market, its sugar could be sold much cheaper, as is evidenced by the rapid fall of sugar prices in the sixteenth century.

The capital needed for the American sugar plantations was supplied by merchants of Lisbon (apparently many Jews), and by nobles who had acquired wealth in the spice trade of East India. Only laborers were scarce or even entirely lacking, but this problem was solved in an ingenious but cruel manner by the importation of African Negro slaves. Thus every continent had a share in the rise of the plantation system in the New World: Europe furnished the capital, Asia the sugar-cane, Africa the laborers, and the Americans the climate and soil.

The plantation system as we know it to-day had its first development in the American tropics. Here also for the first time crops other than sugar-cane were raised under this type of economy: indigenous tobacco, cotton, cocoa and, most surprisingly, in the middle of the eighteenth century, African coffee. In the early days small and middle-sized holdings often developed near large plantations to grow these new crops, but our knowledge of these types of agricultural economy is very limited. Until the beginning of the nineteenth century all these types of enterprises were found only along the coast of Brazil and in the French and British West Indian Islands.

The Negro revolt in French Haiti in 1789 and the abolition of slavery in the English colonies in 1833 shook the plantation system, which until that time had been very stable, to its very roots and caused a new migration. Then for the first time the plantation system reached very significant proportions on the Spanish islands of Cuba and Puerto Rico, spread to the continent, and developed in Venezuela, Colombia and Central America, where indigo and, even more important, coffee were the chief products. Coffee plantations now also began to migrate through Brazil.

Much more extensive in area, however, and economically more important, was a kind of retrograde shifting of the plantation system from America over Africa to Asia, whence its migration had begun a thousand years earlier. The rise of steamship transportation and the later opening of the Suez Canal favored the development of these new plantation areas, as did the continuation of slavery in tropical Africa until 1880 and the availability of a large number of cheap laborers in tropical Asia.

In tropical Africa, which is very difficult of access and is inhabited by free Negroes who resist attempts to force them to work for wages, the plantation system is still unimportant. Only on the islands of Saint Thomé, Mauritius and Réunion has the plantation system attained great significance since 1830.

In the islands and peninsulas of tropical Asia, however, the plantation system has become the predominant type of economy. Here even those plants which in other tropical regions were simply acquired by a gathering economy are

raised on plantations; among these are cinchona, rubber and recently the African oil-palm. The transferring of cultivated plants from one continent to the other required great expenditures of money for scientific research, especially for plant-breeding and seed selection. The private entrepreneur was not fitted for this purpose, and therefore in the Asiatic tropics the plantation system was developed by joint stock companies. In the same manner and with the same success the newest branch of tropical American plantations—the banana culture—was built up for the market of the United States on a large-scale capitalistic basis. The capital here is needed not for the cultivation or preparation of the product, but for its transportation in special freighters.

The economic and social life of the tropics has been widely influenced by the plantation system. The Europeans brought capital and knowledge, the countries contributed soil and the natives labor. In this process the natives were often deprived of their land, uprooted from their social environment and transformed into a landless proletariat, despite the abundance of land in the tropics. Therefore, many people condem the plantation system *per se* and propose to leave the entire production of tropical goods to the natives. Besides these social and economic aspects, more and more ethical considerations are advanced by the opponents of the plantation system. The welfare and progress of the natives, in their opinion, should be the only, or at least the dominant objective of colonial policy. Under no conditions, they say, should the natives be deprived of their land, because only on their own soil do they have the opportunity of preserving their national life.

In opposition to this ethical conception the adherents of the plantation system offer economic arguments. The natives, they point out, because of their primitive economic methods are not fitted to produce all tropical goods so necessary for the inhabitants of the higher latitudes. Such products as sugar, sisal, quinine, etc., which require industrial preparation, can be grown only by Europeans (the word used in its cultural sense) and not by the natives. Even in growing products which can be easily prepared, such as tobacco, coffee, cocoa, tea, etc., the natives are far behind the European plantations in the quality of their products. Only in the growing of annual plants, such as cereals, groundnuts, cotton, etc., which require little or no preparation, are the natives superior to the Europeans. It is not simply a question of plantation system or peasant economy: both types are, in the opinion of these proponents, necessary for the development of the tropics.

Keeping in mind these two points of view, others are pleading for a collaboration between Europeans and natives on the basis of equal rights and equal duties. To the common production, the native should contribute his land and his labor, and the European his capital and his technique. The returns should be divided between the two partners according to certain principles. Unfortunately, the application of this very simple and obvious proposal is almost impossible because of the fact that both partners are very different in racial, cultural and social characteristics, that most natives lack the moral basis for such a collaboration and most Europeans the social will for it. Only under economic pressure has such a collaboration thus far succeeded, notably in the cultivation of sugar-cane, which is relatively simple to grow but very difficult to prepare. In the Fiji Islands, Mauritius, the West Indies and Brazil to-day the natives raise the cane and sell it to the whites, who process it in large central factories. This procedure has the ethical disadvantage that the natives are, for the

most part, not the owners of the land, but only tenants who can be discharged at any time if they do not fulfil their duties.

To remedy the defects of the present policy, English colonial politicians are pleading for another system that will do justice to the natives as well as to the economic interests of the Europeans. Under this proposal the state would mediate between the independent peasant and the white entrepreneur, regulating by legislation the rights of the Europeans and the duties of the natives. This principle, called by M. Leake "triple partnership," found its first practical application in the cotton cultivation of Gezirah (Egyptian Sudan). There the European employer is represented by the Sudan Plantations Syndicate, which is a kind of Chartered Company but without rights on the land. The land belongs to the natives, who are required to till it in a precisely prescribed manner. The syndicate processes the cotton and carries out the irrigation and all commercial activities under the regulations, the barrage and the main canals having been built by the state. The profit is divided in equal parts among the three partners.

This principle seems to be suited especially to dry regions (Indus, Niger), where expensive projects are required for irrigation. But even in those humid regions of the tropics where large areas are not opened and must be developed by means of communication, this principle should be successful, because it combines the advantage of the plantation system with that of the peasant economy and avoids as much as possible the disadvantages of both. This, of course, supposes that Europeans and natives are psychologically prepared for such collaboration and that there is an enterprising state to guarantee its legal foundation.

THE RACE CONCEPT IN BIOLOGY

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THE perennial discussion of the nature of races, particularly of those in man, has become especially lively, frequently acrimonious and notoriously inconclusive during the last decade. Although the problem obviously is in part a biological one, biologists have, with few exceptions, disdained to take part in the debate. An apparently good reason for this forbearance is that the debate on the "race problem" is not conducted on a scientific plane at all. Yet biologists can not escape a part of the blame for the disrepute in which the race problem has fallen. The plain fact is that in biology itself no clear definition of what constitutes a race has been evolved. The existing concepts are either fundamentally unsound or so ambiguous as to be of little use for rigorous thinking. The refined analytical methods of modern genetics may permit a better insight into this problem to be gained than was possible in the past, but the work in this field is now barely begun. The purpose of the present article is to outline the salient features of the situation.

Most taxonomists and anthropologists cling perforce to the habit of describing races in terms of averages of morphological and sometimes of physiological and psychological characters. We are told that the average Eskimo has such-and-such a height, cephalic index and intelligence quotient, while different sets of figures are given for the average German or Hottentot. This method is, because of its simplicity, undeniably convenient for a rough description of the observed variety of humans or of other living beings. The trouble is that it leads to a hopeless confusion when an analysis of the underlying causes of this variety is attempted.

A race defined as a system of averages or modal points is a concept that belongs to the pre-Mendelian era, when the hereditary materials were pictured as a continuum subject to a diffuse and gradual modification. Genetics has established that the hereditary material, the germ-plasm, is not a perfect continuum, but rather a sum of discrete particles, genes, which change one by one by mutation. This is no trifling distinction, and its corollaries must be appreciated. If germ-plasms could blend with each other as a water-soluble dye commingles with water, every interbreeding population would soon reach a reasonable uniformity, and every individual would in a very real sense be a child not only of its parents but of its race as well. A "pure race" would be formed in each locality occupied by the species. With the germ-plasm being particulate, the variety of genes present in a population tends to be preserved intact indefinitely; the genetic constitution of an individual does not necessarily lie midway between those of its parents; some of the genes of an individual may resemble those commonly present in the population from which it sprung, while other genes may be identical with those usually found in representatives of another race. Except in asexually reproducing organisms, pure races can be formed only under very exceptional circumstances (a long-continued inbreeding of close relatives). Since the germ-plasm is particulate, the variation within a population can adequately be described only in terms of

the frequencies of the variable gene alleles and of their combinations. Differences between populations must likewise be stated in terms of the differences in the frequencies of genes present in them.

A geneticist can define races as populations that differ from each other in the frequencies of certain genes. The obvious flaw in such a definition is that differences in gene frequencies may be quantitatively as well as qualitatively of diverse orders. The statement that two populations are racially distinct really conveys very little information regarding the extent of the distinction. This can be made evident by a series of examples illustrating the different degrees of racial separation. The examples given below concern mostly lower organisms, and particularly the small flies belonging to the genus Drosophila. The reader may be inclined to question the applicability of the conclusions reached through studies on this material to organisms in general, and particularly to man. Although in dealing with man the complications resulting from his social organization must not be lost sight of, the laws of heredity are the most universally valid ones among the biological regularities yet discovered. The mechanisms of inheritance in man, in the Drosophila flies, in plants and even in the unicelluars are fundamentally the same. The race concept is very widely applicable, at least among the sexually reproducing forms of both the animal and the plant kingdoms. It can be elucidated most effectively through use of a favorable material, which is, for technical reasons, readily amenable to the application of the experimental and quantitative methods of modern genetics.

The fly *Drosophila pseudoobscura* is a species widely distributed in western North America. Although its representatives from any part of its geographic range appear to be similar externally, genetic analysis reveals a considerable variability under the guise of external uniformity. The variability concerns both the gene arrangement and the gene contents of the chromosomes. Genic variability is displayed in the occurrence of mutant genes that affect the external structures, viability, development rate and other characters. Most of the mutants are recessive to the "normal" condition, and rare enough so that only heterozygotes occur in natural populations.

None of the populations of *Drosophila pseudoobscura* so far examined proved genetically uniform; in every one of them some individuals carried chromosome structures and mutant genes not present in others. Every population may be characterized by the incidence of the genetic variants present in it. Comparison of populations from different localities usually shows them to be unlike, since some of the genetic variants present in one either do not occur at all or occur with different frequencies in others. It is astonishing that even contiguous localities may harbor different populations. In forms which can move only very slowly, such as land snails, differences of this kind have been known for many years. Yet similar differences are observed in the much more mobile Drosophila. In one instance a statistically significant "racial" difference has been observed between populations of localities about 100 meters apart, although the intervening terrain contains no obvious barriers that could impede the migration of the flies. Mobility of an individual organism does not always prevent an extremely fine subdivision of the population of a species into local races. Studies of Dahlberg and others suggest that such a subdivision may occur also in man, since the incidence of certain genes may be different in populations of neighboring villages.

More unexpected still is the fact that

the genetic composition of a population of *Drosophila pseudoobscura* does not remain constant with time. In certain populations from California the incidence of various chromosome structures has been observed to change not only from year to year but from month to month. The causes of such alterations are as yet not clear. The most probable conjecture is that the food sources are unevenly distributed in the territory inhabited by the flies, and that a single or a few individuals which first reach and monopolize an abundant food supply leave an offspring large enough to impress their individual characteristics on the population of the surrounding area. As shown by Sewall Wright on basis of theoretical considerations, both temporal changes and a gradual drifting apart of the genetic composition of local colonies are expected to occur where the effective sizes of local populations are limited. It seems, then, that local populations may be effectively small even in species possessing as good locomotion means as Drosophila. Perhaps an analogous situation in man is the occurrence of villages in which some family name, the heritage of a prolific early settler, is much more frequent than in the population of the surrounding territory. However that may be, changes in the racial composition of local populations may be observed in nature well within a human lifetime. Evolutionary changes in nature are not too slow to be observed directly.

The drifting apart and the consequent racial differentiation of local populations is a process which, by itself, can not be regarded as an adaptation to the environment. It is rather the forerunner of an adaptive differentiation. Genetic changes which arise in a species are subject to natural selection which eliminates the unfit and preserves the valuable variants and the populations in which such variants become frequent. Since the environment is seldom uniform throughout the distribution area, the species differentiates into local races that are adjusted each to the environment prevailing in its particular habitat. Such local races, termed by Turesson ecotypes, do not, as a rule, form continuous populations over large parts of the species area. They recur wherever the proper environment is available, while the intervening localities are occupied by different ecotypes or not inhabited by the species at all. Ecotypic differentiation has been described in many plants by Turesson, J. Clausen, Gregor and others; among animals this phenomenon seems less wide-spread, possibly because the mobility of most animals makes them less dependent than the plants are upon the micro-environment of their habitat. Nevertheless, Dice and Blossom have shown that in the mammals of the North American desert the coat color becomes darker or lighter, depending upon the prevailing shade of the soil on which they live. Dark ecotypes occur on the outcroppings of lava, and light ones on stretches of light sand. An important fact is that ecotypic differentiation does not, as a rule, involve the entire mass of individuals residing in any particular habitat. Thus, the light average shade of the coat color in mammals inhabiting light sand is due merely to a greater frequency of lightly colored specimens in sandy localities, although the darkest individuals on light soil may be much darker than the lightest ones on dark soil.

While the exigencies of adaptation to the strictly local and recurring conditions of the habitat lead to the formation of ecotypes, adaptation to more general variations in the environment results in formation of geographic races (otherwise known as subspecies or ecospecies) which occupy more or less continuously definite parts of the species area. Taxonomists are well aware of

the fact that the differences between geographic races are slight in some cases and much more striking in others. Since the environment changes more or less gradually as one passes from one region to another, the changes in the appearance of the species population may be correspondingly gradual. Where a definite geographic boundary between races is discernible, the races are nevertheless found to merge into each other in at least a narrow boundary zone. This situation is described by taxonomists as "overlapping" or as presence of intermediates between the races. This is a very misleading way of stating the observed facts, for it implies the notion of "pure races" the intermediates between which are sometimes formed. It is more accurate to say that the frequencies of the variable genes change more or less gradually or abruptly during the passage from one portion of the species area to another. If the characters distinguishing races are examined one by one, geographically graded series or, to use the term recently proposed by Huxley, "clines" are encountered. The clines in gene frequencies are what cause the appearance of clines in the outwardly visible characters. The naive concept of pure races connected by intermediates must be replaced by the more authentic one of the varying incidence of definite genes. The idea of a pure race is not even a legitimate abstraction: it is a subterfuge used to cloak one's ignorance of the nature of the phenomenon of racial variation.

As a general rule, the further two populations are removed geographically the greater are the genetic differences between them. In *Drosophila pseudoobscura*, this rule is infringed upon chiefly where very small distances are involved, since the fluctuations in the composition of the population in any one locality (see above) may be large enough to obscure the more general geographical trends. Thus, the variations in the local populations on Mount San Jacinto, California, appear to be haphazard. The localities from which these population samples were taken are from 100 meters to about 25 kilometers apart. Populations from Mount San Jacinto and from the Death Valley region, a distance of about 400 kilometers, are difficult to distinguish if only small samples are available. The difficulty is alleviated if a number of large samples from several localities in each region are studied. Comparing the data for the eastern and the western parts of the Death Valley region, Mount San Jacinto, Mount Wilson, San Rafael Mountains and San Lucia Mountains, California, we find pronounced east to west racial clines. The populations inhabiting Texas are, however, so different from those of California that a single small sample can be determined as coming from one or the other of these regions. Nevertheless, the ability to distinguish groups of individuals, populations, does not necessarily imply that every individual may be classified as a representative of one or the other races. Thus, some individuals from Texas are identical in chromosome structure with those from California, although the Texas and California races as groups are undoubtedly distinct.

While the process of "raciation" must be regarded as predominantly an adaptive one, it does not follow that every difference in the gene frequencies is a direct result of natural selection. Some of the characteristics distinguishing races appear to be adaptively neutral. Without going into the details of this very perplexing problem, one may say that the racial subdivisions of a species are a product not only of the environment now existing but also of a

long historical process of evolutionary development. A race inhabiting a country is what it is, not only because it lives there but also because it came from a definite source, following a definite distribution path or paths.

Superior adaptive types, having originated in different parts of the species area, may spread and finally confront each other across a more or less narrow boundary zone. When this stage is reached, the races may develop isolating mechanisms that would prevent them from interbreeding and hence from exchanging genes with each other. The establishment of isolation connotes the transformation of races into separate species and is therefore outside the scope of the present article. The point which should be made clear here is that a race becomes more and more a reality, and less and less an abstraction, as it approaches the species rank. Species attain a degree of existential concreteness which makes them independent actors in the drama of life. In terms of this histrionic analogy, races of a species may be likened only to members of a choir. The prime characteristic of a species is that individuals belonging to it are prevented from interbreeding with those of other species, but not with each other, by physiological isolating mechanisms. It is, therefore, legitimate to speak of pure species (contrasting them with hybrids between species). Yet, identical gene variants continue to occur in races that are well advanced toward the species rank, as well as in separate species.

The description of the racial composition of a species in terms of the variations in gene frequencies presupposes a careful genetic analysis of the material under study. Unquestionably, this is a slow and difficult task, especially where, as in man, the conditions for genetic work are unfavorable. A satisfactory insight into the nature and significance of the racial differences in man demands far more extensive and detailed information than is now available on the mode of inheritance of the characters causing interracial, as well as intraracial, variability; scientifically controlled data on the manifestation of the diverse genetic conditions in various environments; and a thorough knowledge of the incidence of the determining genes in the class, caste and race subdivisions of the mankind. Evidently, this task can be accomplished only at the expense of concerted efforts of many scientists and organizations in different parts of the world. Yet, the difficulty of the task is not a sufficient reason to cling to the outworn methods of racial study, the inadequacy of which is quite plain, and still less is it a reason for erecting far-reaching theories on the basis of admittedly faulty data. To do so would be a travesty on science. It is said that Menaechmus warned Alexander the Great that "There is no royal road to mathematics." There is no royal road to genetics either.

RELIGIO SCIENTIAE

By CHAUNCEY D. LEAKE
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IN the October SCIENTIFIC MONTHLY the Reverend John S. O'Conor, S. J., professor of physics, Georgetown University, asks "Why do men of science refuse to approach the subject of religion from a scientific viewpoint?" The answer most probably accurate for most of them is that they are afraid to. The fear may be not so much of the subject as of hurting the feelings of the many people who are intensely interested in it.

The purpose of this article is not so much to try to answer the Reverend Professor O'Conor's question, as it is to try to point out that his subsequent conventional argument is scientifically questionable. Many older and more considerate scientists may wonder why any one concerned with science should bother with the Reverend Professor's time-worn arguments. He relates them by analogy, however, to current physics. As a result, practical and busy scientists or laymen may feel that if the essay stands unchallenged, no logical answer is possible. While even slight sophistication in dialectic may raise prompt doubt in the casual scientific reader of the article, lack of time on the reader's part may prevent adequate analysis to justify the skepticism. I am venturing this challenge with full realization that I am plunging into philosophical wildernesses, without the qualifications to pose as a competent guide therein.

It is my feeling that the Reverend Professor O'Conor welcomes discussion of his article, for he may agree that debate may help to clarify the problem, and to stimulate more interest in it on the part of scientists. It may be wise for scientists these days to pay more attention to the general implications of their efforts. Philosophy still has a place in our intellectual affairs if we can persuade ourselves to attempt the co-ordination of our general knowledge with our common desires, as Dewey might put it. Walter Lippmann in "A Preface to Morals," New York, 1929, reminds us that this was part of the wisdom of Confucius, and still is a function of religion.

For those scientists who may be seriously interested in this matter, but who may not be familiar with readily obtainable surveys of thoughtful opinion on it, let me suggest consultation of the critical bibliographical note at the end of H. L. Mencken's "Treatise on the Gods," New York, 1930. The outstanding sources remain "The Catholic Encyclopedia," 16 vols., New York; J. Hasting's "Encyclopedia of Religion and Ethics," 13 vols., New York, 1908, and A. D. White's "History of the War of Science with Theology in Christendom," New York, 1896. An entertaining and fair summary of philosophical development is Will Durant's "The Story of Philosophy," New York, 1930, and Henry Alperin's "The March of Philosophy," New York, 1934.

DEFINITIONS

As the Reverend Professor O'Conor points out, it is pertinent to begin our discussion by trying to define our terms in a manner acceptable to all. While he proposes a definition for religion, he neglects to give similar consideration to science.

Father O'Conor says:

> the etymological or nominal definition of religion is open to two interpretations, one which is based on the notion of a bond (from the

Latin *religare*, to bind) and another which stems from the Latin derivative *relegere* or *religere*, to treat carefully, to ponder or meditate. . . . An unbiased study of the history of religions and of comparative religion sustains a position which maintains that, despite the presence of admixtures such as ancestor worship and accretions of magic and witchcraft, the notion of a supernatural or supreme being is contained at least implicitly in practically all religions. So that on the first interpretation of the nominal definition of religion the idea of God is introduced historically as the term of the bond between man and a higher being, while on the second interpretation this supreme being appears on the same historical basis, as the object of man's meditations.

While this definition conforms to the usual and conventional one, it is hardly adequate for our problem, since it begs the question and gives an answer in which the Reverend Professor O'Conor is interested. For our proposed discussion would it not be simpler to define religion more generally as the *faith* or *belief* one has with respect to the relation between one's self and one's environment? There is no logical or factual necessity of which I am aware that requires that one's faith or religion either nominally or historically must include recognition of a supernatural or a supreme being. That it usually *does* historically is no reason why it always *must*. According to the dictionaries, current usage, limited though it may be, permits the broader definition which I have proposed.

We may also follow usage, as indicated in the dictionaries, as a guide in defining science. May we assume that science is the body of agreed upon and objectively demonstrable knowledge about ourselves and our environment? If so, we may go on with St. Thomas and say that where science ends faith begins. On the basis of these definitions one might say that whereas religion is what one *does* or *wants to* believe about one's self and the universe, science deals more with what is logically and demonstrably *permissible* to believe about one's self and the universe. Science seems to be concerned chiefly with estimating the limits to faith, while dogmatic religion seems to be more concerned with trying to guide the steps of blind belief. Philosophically science tends to be materialistic, pragmatic, realistic, while the trend of religion is idealistic, intuitive, subjectivistic.

Aim, Spirit and Method of Science and Religion

More to the point would be to examine the aim, spirit and method respectively of science and religion. If these may be harmonized, and I believe they may be, then science may become a part of religion and *vice versa*. As forms of human activity they're like the obverse and reverse of the same coin. Religion represents the subjective approach to the universe, science the objective. The difficulty may be simply that through the chicanery of word symbolism the devotees of both wish to be "heads."

In his preface to "The Direction of Human Evolution," New York, 1921, Edward Grant Conklin attempts a definition of the aim, method and spirit of science. He identifies the aim of science with that of religion, to know the "truth" about ourselves and our environment. By the abused idea symbol "truth," he means an objectively demonstrable and intellectually coherent explanation of ourselves and the universe. While appreciating the Platonic ideal of absoluteness in "truth" as desirable, the spirit of science suggests, as C. J. Herrick emphasizes[1] that scientists recognize that knowledge of ourselves and our environment is in the process of acquisition and agreement and will probably always remain so. Scientists dodge Paul Elmer More's "Demon of the Absolute," Princeton, 1928, by admitting honestly that what is called the "truth" about ourselves and the universe is tentative and subject to modification. It is not

[1] *Jour. Philosophy*, 33: 169, 1936.

clear that the spirit of religion suggests to its devotees a similar relativeness for "truth." Most religious leaders seem to consider their particular "truth" as immediately absolute, and therefore binding on every one, whether agreed to or not.

The spirit of science, unlike its aim, seems to be a little different from that of religion. Conklin suggests that the spirit of science is essentially concerned with freedom to seek the "truth." He emphasizes that the spirit of science implies not only freedom to have and to express any view for which there is rational evidence, but also recognition that knowledge of ourselves and the universe is incomplete and subject to revision, and that there is no legitimate compulsion to belief beyond the voluntary acceptance of demonstrably rational evidence.

It is not easy to try to describe the spirit of religion, but it may be inferred from the conduct of religious leaders, whether one considers the great ones of history or living preachers and churchly dignitaries. The spirit of religion seems to be blissfully naïve, and intrigued by the naturally improbable. It encourages introspection, contemplation and self-pity. It bathes in mysticism, is enthralled by symbolism and clothes itself in vagueness. It seems to be fascinated by magic and the incomprehensible, and is not disturbed by the paradox of believing in the reality of the unreal. The spirit of religion promotes prophecy, but in a retributive or intuitive manner, far removed from the sort of prediction ventured by science on the basis of calculable probability.

The spirit of religion seems to be concerned greatly with the task of persuading people, by hope or fear, to socialize their conduct. It promotes standards of behavior, and assumes an ideal ethic. Here a serious difficulty arises. Refusing to confine itself to the limits of scientific knowledge, which it rejoices to transcend, the spirit of religion roams as far as the human imagination can go. The resulting great variety of faith and belief produces continual increase in the astounding number of religious sects. Even with the common basis of agreed upon "authority" in the Bible, divergent doctrines develop to the point of scandal in Christianity, and compromise its ethics, as Niebuhr tacitly admits.[2] Lacking objective criteria or data on which agreement may be arbitrated, as in science, social harmony is difficult for religious leaders to obtain except by appeals to some "authority" operating through fear, hope or other emotional force. The spirit of religion thus seems to be reflected more in emotional reactions than in intellectual responses.

George Santayana[3] might go on to compare the spirit of religion to that of an impatient, impulsive and very attractive adolescent girl, who, when curbed by the precise and pedantic spirit of science (whom she would call "inhuman"), might petulantly cry, "You can't keep me from dreaming." The spirit of science seems to be tolerant enough to appreciate the spirit of religion, to be attracted to it as an object of study, and indeed even to love it with nostalgic remembrance of its own adolescence. On the other hand, the ever young spirit of religion, like Peter Pan, can hardly be expected to have much regard for the staid and preoccupied spirit of science beyond an uncomprehending deference. Whether a marriage between them could ever be consummated is as debatable as whether such a marriage is desirable.

As I understand the situation, a scientist can not take without protest the Reverend Professor O'Conor's definition of the method of science as being "one which accepts facts and attempts to fit them into a theory or system." This

[2] "An Interpretation of Christian Ethics," London, 1936.

[3] "Reason and Religion," New York, 1918.

definition assumes *a priori* the theory or system of thought, an assumption which may be questioned by a scientist, but not by even so liberal a philosopher as Hugh Miller.[4] The method of science seems to be more concerned with the establishment of fact. The successful scientist is usually pragmatic. He may proceed in either of two broad ways. In one he may be chiefly empirical, by observing and describing as carefully as possible some phenomenon in his environment or himself, and then go on to offer a tentative explanation of it, the validity of which he may then test by experiment, confirming or modifying his ideas in accordance with the results of such experiments. This is the way of the life sciences. In the other he may be more rationalistic. He may indeed proceed somewhat along the way suggested by the Reverend Professor O'Conor, but in reverse. He may try to build by experimental reasoning within the strict limitations of logical consistency, a coherent ideal system with which some of the details of the universe about us may be found, on experiment, to correspond. This is the mathematical way.

It seems to me that the usual method of religion, which one may trace through all history, and which one may find exemplified in the Reverend Professor O'Conor's "Approach," is to assume "God" and "immortality," and then relate everything else in experience to these assumptions. However dialectic it may be, the method of religion is basically anthropomorphic. In a Kantian sense the method of science is anthropomorphic also, but it implies deliberate discounting of psychological or emotional factors. In following the method of science, a scientist must always guard against confusing his symbols with what they may represent. In developing Aristotelian logic, religious leaders have sometimes permitted this confusion to carry them to conclusions impossible under more rigorous scientific inquiry. The method of religion seems to be directed toward the gratification of the Microcosm, while the method of science admits the limitations imposed by the Macrocosm. Religion may yet adopt the method of science, but science can not consciously adopt the historical methods of religion.

[4] "History and Science," Berkeley, 1939.

Authority in Science

Referring to scientists the Reverend Professor O'Conor puts three subtly leading questions, which, no matter how answered categorically, might force the unwary to accept a position incompatible with the free spirit of science:

> Are they *assuming* without reason that faith and science are irreconcilable so that any attempt at reconciliation is doomed to failure from the start? Do they *postulate* without further examination that dogmatic religion is necessarily and essentially incompatible with the scientific method? Do they *deny a priori* that authority as a source of true knowledge must be abandoned *in principle?* If they do then they are no longer acting in the role of scientists but are subscribing to propositions the truth or falsity of which they show no evidence of having investigated.

To these questions, replies are ventured which are framed in the light of the definitions proposed for religion and science. First, it is my opinion that all scientists who have thoughtfully considered the matter appreciate the reciprocal relations of faith and knowledge, and that they ordinarily reconcile religion and science as far as the implications of knowledge permit. Second, I think it is clear from the attempted definitions that dogmatic religion is incompatible with the scientific method as long as dogmatic religion *requires* the postulation of a first and unproduced cause of the universe, or of the *necessary* assumption of any other idea for which direct objective evidence is lacking. When a consideration of multiple hypotheses is appropriate to a problem, science permits the postula-

tion of any idea not logically absurd or directly refutable by available evidence, but it can not permit either bias or commitment *a priori*. Science makes a special point of discounting any judgment which *may* be influenced by psychological factors of training and conditioning, or emotional factors involving wishful or fearful thinking of any sort. After rather careful examination scientists seem to have come to the conclusion that the ordinary manifestations of the methods of dogmatic religion are incompatible with those of science. Third, it seems clear from a consideration of what science is about that it could not exist were authority in itself to be acknowledged as a source of "true" knowledge. In obtaining or interpreting data in any scientific field, one of the necessary duties of a scientist is to raise doubt regarding the intellectual validity of giving more than respectful consideration to any "authority" as such, since there is always the probability that the "authority," being human, may have an axe in the matter to grind. Voluntary and uncoerced agreement among reasonable competent scholars in a field, on the basis of the objective evidence available, constitutes the only "authority" which science can recognize. Appreciation of the relativeness and tentativeness of "truth" or "knowledge" of ourselves and the universe and good-humored alertness to the human qualities of "authority" are potent factors against the development of a scientific "canon." None the less a conscious effort is also necessary on the part of scientists to prevent the growth of any "authority" which may impede the freedom of science. Sincere and pertinent skepticism remains a fundament of science and a scientist is duty bound to try to apply it as vigorously to his own data and opinions as to those of others. This discussion of the questions asked by the Reverend Professor O'Conor indicates the absurdity of the conclusion he draws from the gratuitous answer he makes to them.

The Reverend Professor O'Conor's plea for deference to "authority" in religion and science has serious implications these days. There are reciprocal relations in science and democracy which require freedom for operation. From our discussion so far it would seem that science could be employed much more satisfactorily as a curb to the roving and restless spirit of religion than an arbitrary "authority." The function of a church seems to be chiefly to exercise "authority" in religion. Historically it has been demonstrated that science can flourish only when it is independent of any such "authority." There is a peculiar danger now that "authority" may sweep democracy from the earth. It is the duty of scientists to remain conscious of this danger, and thus to resist to the utmost any attempt to foster respect in science for any arbitrary "authority" as such.

Proof of the Existence of God

Having set the stage by leading questions, and by a definition of religion which states his conclusions, the Reverend Professor O'Conor undertakes "a *proof* of the existence of God." He begins this by stating categorically, "The position taken here is one which is entirely unassailable on anthropological grounds." Such a statement may be his opinion, but I think he will be fair enough to admit that other opinions are not only possible but probable. Since the whole of the Reverend Professor O'Conor's position is dependent upon "the proof" which he says he is going to furnish, one may be justified in expressing surprise that "the proof" is difficult to find. The "proof" offered consists chiefly of begging the question and vague analogy. Granting the Reverend Professor O'Conor's assumption of the objective existence of God, the rest of his

position follows logically and along the lines established by dogmatic religions everywhere. Its novelty consists only in its relation to current physical ideas.

But why grant his assumption? Why not acknowledge it for what it is, namely a postulate of great interest historically, and of great power traditionally. The pragmatic observation that the logical edifice erected upon it has worked and continues to work, is no proof of its correctness or that it corresponds with reality through any necessity scientific, logical or otherwise. It remains an interesting philosophical problem to guess whether or not a logical system erected upon the contradictory opposite of this assumption would not work as well.

When a problem is offered to science, on which it is difficult to obtain direct objective and measurable data, it is often approached by proposing multiple hypotheses. These possible explanations are then examined as carefully as can be with reference to all available evidence for or against them. The one having the greatest probability of coordination with acceptable "reality" is tentatively selected as a working basis for further studies. This does not preclude, of course, further investigation of such hypotheses as may have been rejected.

Many hypotheses have been proposed regarding God. Those that postulate existence of a supreme being usually resolve themselves in discussion to matters of definition. Passing by such philosophically subtle postulates as Hegel's *universal reason,* or Paulsen's *universal will,* we may illustrate our difficulty by reference to such relative opposites as are represented by common idealistic and materialistic notions of God. The traditional hypothesis, in which the majority of people seem to believe, is that God is an ideal and universally dispersed entity of omniscience and omnipotence. Rather far removed from this definition is the more sophisticated idea that God is the sum total of the capabilities of some ninety-two elements, their possible combinations and permutations and the forces that are associated with them. While the Reverend Professor O'Conor might agree to either of these definitions, he would probably insist that man has no share in developing either. On the contrary he would probably insist that "God" on either definition reveals Himself to man, in the former case through the visions of religious leaders and in the latter through the search of scientists.

There remains another sort of hypothesis. This involves the notion that man and the universe are made of the same stuff, and that what people have been calling God is as much themselves as not themselves. This implies that the ancient dualism of "mind and matter," or of "self and non-self," is a postulate of faith and has no correspondence with reality. From this position the question of the objective existence or non-existence of God becomes irrelevant and immaterial. Perhaps this is the implication of Kant's famous antimonies. *In the calculus of science, reality is as asymptotic to the idea of a first and unproduced cause as it is to the idea of infinity.* This statement is one which expresses the matter in strict scientific terms. While some of these terms are incomprehensible literally, like infinity, they are useful working symbols—but not "facts." In this sense, perhaps, Dr. J. E. Wishart[5]

[5] Hibbert Jour., 38: 447, July, 1940. Dr. Wishart, a distinguished theologian, in kindly reviewing the manuscript of my essay, roundly condemns my assumptions and conclusions and gently expresses a fitting pity for me and mine. More seriously he doubts that there can be religion without God, and thus feels that my working definition of religion is unacceptable. The Right Reverend Edward Lamb Parsons, Bishop of California, also was generous as ever to be interested in my manuscript, and he has somewhat the same opinion as Dr. Wishart. Both feel that attempted coercion by arbitrary authority may

proposes that we pragmatically use the idea of a first cause, incomprehensible though it may be, because it explains the situation better than any other hypothesis on the problem.

Concluding Notes

It is natural for the Reverend Professor O'Conor, being a physicist and seismologist, to develop his position from the standpoint of physics and mathematics. But in requesting consideration for a scientific approach to religion he can not neglect other fields of scientific endeavor, particularly biology, since man is so closely and clearly related to other mammals, albeit more remotely to other living things. One may wonder whether there was deliberate omission of any consideration of the possible bearing on religion, faith or belief, of current contributions in physiology, psychology and psychiatry. To one familiar with recent advances of knowledge in these fields, the anthropomorphic features of religion are not accidental. If the explanations of man's behavior in relation to his environment as offered by scientists in these fields, are considered to be scientifically valid, then the premises and position postulated by the Reverend Professor O'Conor and by conventional religious dogmas of all sorts, become dubious indeed.

Since the Reverend Professor O'Conor refers to miracles, we might pay our respects to them here in passing. Without even raising the question of the degree of probable accuracy of the canonical accounts, one may apply our knowledge of psychological and psychiatrical processes to the miracles as reported, and find that they are capable of receiving full and adequate natural explanations. Since my statement is a contradictory opposite of the Reverend Professor O'Conor's, one's judgment in the matter depends on estimating the degree of probability of correctness of correlation; but with what standard? An attempt has been made to define the standards of science and religion. Which do you choose? For a scientific approach to religion, one would expect that scientific standards would be applied to religious claims.

We order our lives on the basis of what we believe. The source and character of our beliefs appear thus to have great importance. If our faith or religion consists of expressions of fond hopes, pathetic desires and anxious wishes, inspired by greed, jealousy and fear, nothing very satisfactory for ourselves or society is likely to result. On the other hand if our faith or religion is based, not upon what we may want to believe, but upon what is possible for us to believe in view of the limitations imposed on us by our knowledge of ourselves and our environment, it would seem that a little more reasonable and individually responsible ethic might be derived. This is Warner Fite's "Individualism," New York, 1911, in which he points out that the interests of conscious individuals are harmonious. It is the point of Dewey's suggestion of harmonizing desire with knowledge or experience, and of what Walter Lippmann thinks was meant by Confucius, Jesus and Buddha.

Professors E. G. Conklin and C. J. Herrick have come independently to this conclusion from scientific considerations relating to biology.[6] With them Professor S. J. Holmes[7] and Dr. George Sar-

be as dangerous in religion as in science. Father O'Conor graciously acknowledged receipt of the manuscript, and commented generally on it, but has not yet had time to dissect it in detail. The italicized statement may be made more general as follows: *The reality of any moment is as asymptotic to a first and unproduced cause or to a final and end result as it is to infinity in any direction of space or in time either past or future.*

[6] Scientific Monthly, 49: 99–110, 295–303.

[7] *Science*, 90: 117–123.

ton[8] also independently agree, that, to put it simply, the probability of survival of human relationships increases with the degree of mutual adjustment, in the relationship, toward mutual satisfaction.

Although stated in the form of a scientific generality, the ethical significance of this principle appears in relation to the common urge for survival and satisfaction. Consciousness of the operation of this principle suggests the wisdom of such altruistic, considerate and magnanimous conduct as is intuitively considered "good" in all ethical systems. The social customs and conventions now with us have so far exhibited survival value in the Darwinian sense. We may apply evolutionary principles to them, and attempt the formulation of a *modus operandi*. Such a formulation constitutes the statement offered. Whether or not it may give a biological and scientific basis for a pragmatic ethic remains to be estimated.

A scientific approach to religion implies the problem of whether or not science can form a basis for religion. The answer is "yes" in the light of the definitions proposed by me, but not on the basis of those proposed by the Reverend Professor O'Conor. This conclusion, not being satisfying to him, will probably be rejected by him, for man remains the measure of all things.

To one impatient with the problem of philosophy in coordinating knowledge and desire, this discussion may appear to be circular. Indeed, unless the Reverend Professor O'Conor and folks like me can agree on definitions of religion and science, we may always find ourselves in the position Fitzgerald ascribed to Omar of coming out the same door wherein we went.

[8] "The History of Science and New Humanism," Harvard, 1937.

SCIENCE AND TRUE RELIGION

A REPLY TO DR. C. D. LEAKE

By The Reverend JOHN S. O'CONOR, S.J.

PROFESSOR OF PHYSICS, GEORGETOWN UNIVERSITY

At the risk of ensnaring further unwary scientists and unsuspecting laymen I am taking this opportunity to point out in some detail the perhaps unconscious naiveté of Dr. Leake's assumption that his criticism of my article "A Scientific Approach to Religion" constitutes a "logical answer" to the same.

His reply is, however, most appropriate at least in one respect; for it serves as a perfect example of that procedure to which I specifically called attention: namely, that of holding up to ridicule some synthetic religion, made to order for the purpose from elements which constitute but a catalogue of inconsistencies and excesses, and by this means attempting to discredit true religion, which has no more to do with this caricature than astrology and numerology have to do with true science.

Dr. Leake begins by taking exception to my definition of religion and substitutes one of his own making which is: "A faith or belief one has with respect to the relation between one's self and one's environment."

I have consulted Sir James Murray's ten-volume New English Dictionary, including the 1933 supplement, and find neither philological nor historical warrant for such a definition. Neither Webster's New International nor Funk and Wagnalls' New Standard dictionaries gives a definition which can be considered the approximate equivalent

of it. Thus the truth of the statement that "according to the dictionaries, current usage permits this broader definition" is yet to be established.

The definition which I submitted *is* solidly established, both historically and philologically, and is the one generally agreed to—conventional, to use Dr. Leake's own characterization.

To take such a definition, and then show by a reasoned proof that the essential element in it (A Supreme Being) has objective existence, or to make up a definition for the occasion, which on analysis displays no criterion for differentiating between the thing defined and the multitude of other reactions to environment which all of us know are *not* religion, which of these two procedures is the more scientific and objective; which, I ask, is the more arbitrary and postulational? When Dr. Leake counters with the statement that because religion historically usually includes the recognition of a Supreme Being—this is no reason why it always must—he is arbitrarily demanding a change in the significance of words. Is it not more in the spirit of science to discuss *what is and what has been* rather than *what might be?*

Dr. Leake cites my neglect to define science, yet later on disagrees with what he calls my definition of the scientific method. He claims that science is more concerned with the establishment of facts than with the attempt to fit them into a system or theory. I question that distinction. Albert Einstein is quoted as defining science as "the coordination of our experiences by bringing them into a logical system." Perhaps he has been misquoted, perhaps his definition is not correct, but I doubt very much that Dr. Einstein will cease working on a unitary field *theory* for the facts of gravitation and electromagnetism when he becomes aware that this is not an essential aspect of science. I also doubt that the successors of Darwin will all repudiate their work as unscientific because they have been attempting to fit the facts of paleontology into the theory of evolution.

An adequate discussion of Dr. Leake's section entitled "Aim, Spirit and Method of Science and Religion" is precluded by the scientific nature of the journal in which this discussion appears, for the entire sequence is made up of paragraphs which are introduced by such subjective indicators as "we may assume," "I believe," "it seems," which are used sixteen times in presenting what purport to be acceptable views on religion, while the attacks on my approach are shot through with a dogmatic positivism which can best be met by a counter-demand for proof.

Near the end of the section just referred to, as well as in subsequent parts of his article, Dr. Leake claims that my "approach" exemplifies the usual method of religion, which is to "assume God and immortality and then relate everything else in experience to these assumptions." Again where an answer is attempted to my so-called "leading questions" the following is found: "I think it is clear . . . that dogmatic religion is incompatible with the scientific method as long as dogmatic religion *requires the postulation* of a first and unproduced cause of the universe or of the *necessary assumption* of any other idea for which direct objective evidence is lacking."

First, let me make it clear that immortality was not even mentioned in my entire article. Secondly, let me emphasize that it is a *proof* of God's existence and not a *postulate* that was the object of my investigation, not, it is obvious, with the purpose of making an exhaustive study of the same, but merely to call to the attention of readers of THE SCIENTIFIC MONTHLY the similarity between the methods of the so-called "time-worn" arguments and those of

modern science. In confirmation of this I again call the reader's attention to the reference given near the end of page 369 in my article. This book (Brosnan's "God and Reason") is a standard text on natural theology in which the proof under discussion is fully developed.

To say that the "proof consists chiefly of begging the question and of vague analogy" is merely to confirm the suspicion that my critic has never taken the trouble to look up the reference in question. If the Doctor had disagreed with the proof referred to and pointed out its alleged fallacies, a basis for further discussion might be had, but to call a proof a postulate seems inexplicable even in the case of one for whom the realm of philosophy is but a "wilderness."

In the discussion on "Authority" much is made of the objectivity of science as indicated by the exclusion of "wishful or fearful thinking" and of the refusal to admit "either bias or commitment *a priori*."

As a scientist I concur completely on these points, but should like to call attention to the third work listed in Dr. Leake's introduction as an "outstanding source," *viz.*, A. D. White's "History of the War of Science with Theology in Christendom." It is amusing to listen to talk of "discounting judgments which may be influenced by psychological . . . or emotional factors . . ." when the author of a book, which is filled with such violent diatribes that it can not be considered by any impartial critic except as a piece of rank bigotry, is held up as an outstanding authority. The inhibitions, attributed by Dr. Leake to most of his colleagues, which prevent scientists from writing on topics they fear will give offense to those interested in religion, would undoubtedly become overwhelming should they consult this reference. But no scholar will be tempted to accept the writings of A. D. White as source material.

My plea for deference to "authority" is characterized as one which "has serious implications these days." It is hardly necessary to point out that the word "authority" should have been understood as meaning *credibility*, namely, that which gives weight to one's testimony, *i.e.*, knowledge and honesty. The politico-social sense of the word authority is quite irrelevant here. To invoke a dubious historical argument against the authority of the Church, based on an ambiguity in terminology, and to reject the historical argument in relation to the notion of God in religion does not seem to be consistent.

I am sure that Dr. Leake would resent, as would any other scientist, were one to claim that it is "science" which is devastating the earth and sweeping democracy from its surface. Yet all will have to agree that science and its principles are helpless to prevent the devastation wrought by those who admit no authority (in the sense taken by Dr. Leake) higher than their own.

There is one statement of Dr. Leake's with which I am at least in partial accord. He says: "Granting Father O'Conor's assumption of the objective existence of God, the rest of his position follows logically. . . ."

A change of the word *assumption* to *proof* would bring apparent agreement on one point.

But even if the word proof were substituted the difficulty would merely be pushed further back and the question could legitimately be asked: Are there not postulates in the proof?

To get at the root difference between Dr. Leake's position and mine we must also ask: Is any scientific conclusion which is beyond the direct evidence of the senses susceptible to "proof"? My answer is yes. There are certain analytical propositions (such as the principle of contradiction and of sufficient reason) which are objectively and immediately evident.

These are not mere postulates but

necessary laws of thought which flow from the laws of being and without which there could be no knowledge. These principles when properly employed in conjunction with sense data lead to certain necessary conclusions regarding the reality of the external world and its origin. Thus if one admits objective evidence and the supremacy of reason to the extent of accepting conclusions deduced by it, although these may go beyond immediate sense data, then one must also admit the absolute validity of the cosmological proof for the existence of God.

If one denies these principles of metaphysics and poses as admitting only knowledge derived directly from sense data, then one is forced to admit that there is no difference between scientific knowledge and the lowest form of animal reaction to sense stimuli. This position of pure sensism, or of positivism, is itself a dogma which has never been rationally established and is rooted in a prejudice which refuses to accept the implications of reasoning.

To preclude the necessity of maintaining an entirely absurd position the laws of thought must at least be assumed as a postulate system—otherwise our sense data could not even be communicated rationally, much less discussed or correlated scientifically.

While not agreeing with or admitting a system of philosophy which claims that all fundamental principles are but postulates, we do maintain that, as far as this controversy is concerned, any postulate system which admits the possibility of scientific knowledge, as it is commonly understood to-day, is also sufficient to establish the existence of God on the same scientific basis. Science to-day is concerned with, reasons about and concludes to propositions which are certainly beyond the direct range of sense data. If this is admitted, the arguments for the existence of God *a fortiori* can not be thrown out unless one is willing to exclude all such concepts as electron, proton, neutron, relativity, quantum theory, and the like.

Let it be clearly understood that the position presented above is not put forward as the alpha and omega of religious systems. It can be considered, however, as the rational basis of natural religion and serves as a preamble to supernatural faith, which is a gift of God, reasonable in itself but not obtained by reason alone.

Regarding the bearing on religion of current contributions in physiology, psychology (experimental) and psychiatry, my reply is that the omission of such considerations by me was indeed deliberate, not through any fear of consequences to true religion (for truth is one and can not contradict itself), but on the principle that it is scarcely profitable to discuss such disciplines unless one's knowledge approaches that of the professional both in depth and interest. Any reply may well be deferred until something more than the hypothetical proposition advanced by Dr. Leake is forthcoming.

The categorical denial of my remarks on miracles has in no way advanced matters on this point. Before making any choice, the prospective student of miracles must become acquainted with the literature. I am therefore appending a few references which may serve as an easy introduction to the subject and will have to be examined and evaluated before there is any serious attempt to posit a judgment.

To close on a note of unity let me express entire accord with the idea that neither my own five-page article, nor Dr. Leake's one of more than twice that length, can be expected to do more than stimulate further interest in a subject that has been vital to men of all times.

If this has been accomplished we can relinquish the discussion with sentiments

akin to those of St. Augustine, and quote from his "City of God," as appositely we hope, as Dr. Compton did last January from his "Commentary on Genesis."

If we should bind ourselves to give answer to every contradiction that the opposing front offers (how falsely, they care not, as long as the denial is made), you see what trouble it would be, how endless and how fruitless. Therefore . . . I would not have you read this volume thinking I am bound to answer whatsoever you or others shall hear objected against it, lest you become like the women of whom the Apostle speaketh, that they were "always learning but never able to come to the knowledge of the truth."

Summary of the Cosmological Argument

Proposition to be proved:

There exists an unproduced first cause of all things existing in the world.

Proof:

There exist in the visible world produced beings.

But the existence of even one produced being necessarily implies the existence of an unproduced first cause.

Therefore such a cause exists.

The major proposition of the proof is evident from internal and external evidence.

The minor proposition may be proved as follows:

The cause of the produced being in question is either unproduced or produced.

If unproduced our conclusion stands.

If produced the question recurs: Whence its producer?

The answer must either finally stop at a *first unproduced cause* and again *our conclusion stands*, or,—

We must admit an infinite series of successively produced causes either dependent on an unproduced cause, or without such a cause. If the series depends for its existence on an unproduced cause *our conclusion again stands.*

If however it is asserted that such a series can exist without an unproduced cause, to *finally* establish our conclusion we must prove this assertion false.

In other words we must prove that—

An infinite series of successively produced causes, without an unproduced cause of it, is absolutely impossible.

It *is* impossible if nowhere can be found an *adequately sufficient* reason for the existence of any one member of it. But nowhere in it can such a reason be found.

It can not be found in the being itself, which we shall call *A*, for *A*, a produced being, could then never have existed, for a being can not produce itself, before it itself exists.

Nor can it be found in any prior cause. For if the *adequately sufficient reason* for *A*'s existence could be found in any one such cause or group of causes then all causes in the series prior to this group could be considered as nonexisting as far as their requirement for *A*'s existence is concerned.

But if any cause in the series is considered as non-existing then all subsequent causes in the series must be considered as non-existing and hence *A* as non-existing.

Hence the hypothesis, that any cause in the series can give an adequately sufficient reason for *A*'s existence, results in the absurd conclusion that *A* can not be existing.

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BOOKS ON SCIENCE FOR LAYMEN

THE CURRENT WHALE OIL INDUSTRY[1]

THE aim of this book, as stated by the author, is "to analyze the economic problems surrounding one of the world's important raw materials of the present time." Whaling, which contributed so much to the wealth of Dutch, Hanseatic, British and American citizens, is traced from its beginnings, the causes of its decline are reviewed, and the background for its revival under Norwegian leadership during the twentieth century is described.

The book commences with a discussion of the importance of whale oil as a commodity in world trade, where it constitutes about 9.4 per cent. of the total volume of foreign traffic in fats. Germany, for instance, in 1935 obtained 54 per cent. of her margarine and lard compounds from whale oil. Whale oil contributed 41 per cent. of the margarine, 28 per cent. of the lard compound and 16 per cent. of the soap manufactured in Great Britain in 1937.

Although whale oil is the chief product of the modern whaling industry, the commercial utilization of a whale carcass yields also whalebone, ambergris, meat, concentrated protein foodstuffs for domesticated animals, fertilizer, hormones, leather and glue. Hence "the value of whales as a natural resource depends essentially on the demand for certain raw materials to be derived from it, on man's technical ability to utilize it, and on his intelligence in refraining from depleting it."

Whaling is now prosecuted largely on the high seas beyond the jurisdiction of sovereign states. It is of especial importance to countries which lack natural resources but have an abundance of labor and industrial facilities to build floating factory ships, whale-catcher boats and transport vessels, and to utilize commercially the products obtained. Consequently, intense international competition has developed into a struggle between the British-Norwegian interests which view whaling as a means for the employment of manpower and capital and the German-Japanese companies which are fostered by their governments to obtain fats and raw materials either for domestic consumption or for conversion into necessary foreign exchange.

Despite efforts at international regulation sponsored by the League of Nations in 1931 and by the Norwegian and British Governments in 1937 and 1938, it has become increasinly apparent that the high standard of efficiency attained by factory ships and whale-catching equipment threatens the continuation of the industry. One obvious shortcoming of these agreements was the reluctance of most of the countries to impose a definite limitation of oil production by fixing maximum quotas for their own whaling industry. In the international exploitation of this resource the competing nations are endeavoring to obtain a maximum share in the catch and at the same time are voicing their fear of excessive slaughter of existing stocks of whales.

The author believes that whales will be amply utilized so long as competing nations find whaling a remunerative enterprise and perhaps even longer by companies subsidized by countries with a deficiency in fats and foreign exchange. World production of whale oil each year is determined by the number of whales caught, by the ratio of blue whales to other kinds of whales in the catch, by the average size of individuals of each species in the catch and by the technical efficiency and economy of oil-processing operations.

[1] *Whale Oil, An Economic Analysis.* By Karl Brandt. Illustrated. xiv + 264 pp. $3.00. June, 1940. Food Research Institute, Stanford University Press.

Since the price of whale oil is mainly determined by prices of competitive fats and since the costs of whaling increase with the decline in the average size of whales caught, these considerations control the remunerative operation of factory ships equipped with costly processing machinery and of the whale-catcher boats that do the killing. New uses of whale oil as food and industrial material and improvement in quality by prompt processing of whales caught has brought about an expanded and diversified demand for this fat. The author elucidates the highly complex play of factors affecting the prices of oil and fats and concludes that whale oil has become the base of the price structure of fats.

The discussion of the transport, storage and marketing of whale oil is followed by a résumé of the influence of tariff duties, excise taxes and other measures devised to protect domestic producers of competitive fats on the marketing of this commodity. The appendix is designed primarily as a source for selected statistical data.

In this well-documented and carefully prepared book, a qualified, impartial observer makes a notable contribution toward a better understanding of the mechanics of the whaling industry.

REMINGTON KELLOGG

FROM BACTERIA TO ORCHIDS[1]

PROFESSOR HYLANDER has written a book such as every botanist has wished he could write but which none of us has been able to produce. It is a big book, over 700 pages, 7½ x 9½ inches, crowded full of remarkable photographs and meaty text in fine print.

This is probably the most comprehensive book on plants that has yet been written for the general reader.

Mr. Hylander classifies and discusses virtually every common type of plant now extant in this country—native and naturalized; he tells of their distribution, their habits, their uses and their various unique and specialized structures which enable them to exist in specific environments.

Here is a world of detailed and exciting information on plants—all the way from bacteria to orchids. The author writes of the seaweeds and shy organisms that grow on the ocean floor; the plants that form a felty mass on the sides of cliffs; the vegetation that stands primly erect in a quiet marsh or lies asprawl on the stagnant surface; the familiar flowers and trees of our American fields, forests and deserts. Here one can learn about plants that kill insects for food; plants that live in cooperative colonies, dividing their labors with evident success; and scores of others. So inclusive is this book that it will be appreciated by amateurs, students and experienced botanists alike.

In gathering his material, Mr. Hylander, who is assistant professor of botany at Colgate University, traveled twice from Maine to California by car and trailer; he has included here over 400 of his plant photographs and line drawings. The book is as fascinating as the world of plants which it describes.

Probably the most serious fault in the book is that it is too big and the print too small. The type would not have been too small if the page had been broken into two columns, but, set as it is in long lines stretching across the wide page, it soon puts the reader's eyes aswim and he lays it down with a sigh only to be intrigued to pick it up again because of its interest. This defect is mitigated by the fact that the book will be used more for reference than for continuous reading.

In a book so large one could readily pick up errors and find many details to criticize. The very numerous line drawings are nowhere near as skilfully done as the photographs and often leave off the details a botanist would wish to see (and which could have been added with

[1] *The World of Plant Life.* By C. J. Hylander. Illustrated. xxii + 722 pp. $7.50. Macmillan Company.

just a little more effort). Too many of the halftones have lost the "snap" evidently possessed by the original photographs and many of them are smutted against the next page by careless printing. There are some expressions that are rather forced in an effort to popularize, like "warfare" among plants which refers chiefly not to competition in their struggle for existence but to parasitism.

But one is ready to forgive the shortcomings of the book for the service it does him. It is to be hoped that a second edition will soon be required and give the author opportunity to make all desired improvements.

ROBERT F. GRIGGS

TWO QUAKER BOTANISTS, FATHER AND SON[1]

THIS, the second volume of a series, "Pennsylvania Lives," gives a very brief account of the lives of two Quakers who had a profound influence on the colonies and became valued friends of their European correspondents. John, the father, with a meager school education became so deeply interested, first in plants and later in many fields of science, that he succeeded in training himself to become a valuable contributor to scientific knowledge. He traveled thousands of miles in the eastern United States from Canada to Florida in his collections of plants and seeds, many of which he sent to European botanists, to whom they were unknown. His descriptions of plants, weather, animals and soils were both accurate and thorough.

John Bartram brought to his farm near Philadelphia parts of his plant collections which with his European exchanges became the first American botanical garden. In this garden he became one of the first to understand sex in plants and to cross-pollinate them.

William Bartram, the son, began his travels with his father at the age of fourteen, on a trip to the Catskill Mountains. William learned to love nature and travel, but he appears to have been so interested in philosophy that his collections and exchanges with his correspondents suffered. He inherited his father's power of keen observation and his descriptions were famous for their vividness. Many of them appear to have been the bases for later descriptions by famous authors. The "Travels," a masterpiece, was published in many parts of the world.

Since these men set so high a standard for accomplishment as to draw the eyes of the world toward Philadelphia, it is to be regretted that so few quotations could be included in this small volume and that the number of copies of the edition is limited to 1,000. It would seem that the reading of this volume might well be a stimulus to many others to overcome difficulties and make contributions to their chosen fields.

L. EDWIN YOCUM

[1] *John and William Bartram.* By Ernest Earnest. Illustrated. xvi + 187 pp. $2.00. 1940. University of Pennsylvania Press.

A PRIMER OF ANTHROPOLOGY[1]

A SUCCINCT popular treatise on man's origin and on early man, by "formerly senior member, scientific staff, Anthropological Department, Welcome Museum," London. Deals with The Beginning of Things; The Ancestors of Man; The Great Ice Age; Men of the Ice Age; The End of the Ice Age; The Men Who Came after the Ice Age; The End of the Old Stone Age; The Middle Stone Age, and The New Stone Age.

A very readable production that may, in another edition, make a good primer on the subject it deals with; but before that it will need considerable mending in various details. Thus the meteorites (p. 7) are hardly "fragments of metal which probably made the original body of the sun"; the skulls of all the anthropoid apes are not all "much rounder"

[1] *Mankind in the Making.* By M. C. Borer. Illustrated. 152 pp. $1.50. 1939. Fred. Warne and Company.

than that of the Pithecanthropus; it is not true (p. 41) that "no other relic of any other member" of the Pithecanthropus family has ever been found; the "migrations" of early man from Africa or Asia to Europe, the separateness, chronology and extinction of the Neanderthal man, and the coming in from some unknown somewhere of the full-fledged *Homo sapiens*, are all outlived assumptions. And there are inaccuracies about the Eskimo and in other matters.

Yet the treatise can not be condemned and may in a future edition be made quite useful. There is a great man in England, Sir Arthur Keith, who for the sake of soundness would probably be glad to assist in setting things straight.

A. H.

DEVELOPMENT OF THE HUMAN EMBRYO[1]

It is a pleasure to welcome the fourth edition of Arey's "Developmental Anatomy." To those who have used this volume on human embryology it needs no introduction. It is still the outstanding text-book in its field.

Although the book is written primarily for the use of serious students, it should not be overlooked as an interesting source book by those who at one time or another become interested in the phenomena of prenatal development. No one can pass by the miracle of reproduction without hesitating to consider the underlying organization and motivation that produces a complicated functional organism from the union of a sperm with an egg. There is a real fascination in the history of development through segmentation, formation of layers of cells and the eventual foldings and growth processes that produce the various organs of the foetus.

There are a great many readers who, having perused a lighter, more popular book on human embryology, will want to learn in greater detail or with closer accuracy what is happening as pregnancy proceeds and the baby develops. This volume will answer those questions in an authoritative reliable fashion as it does for the medical students into whose hands this book will find its way. It is well illustrated, carefully written and an entirely worthy volume.

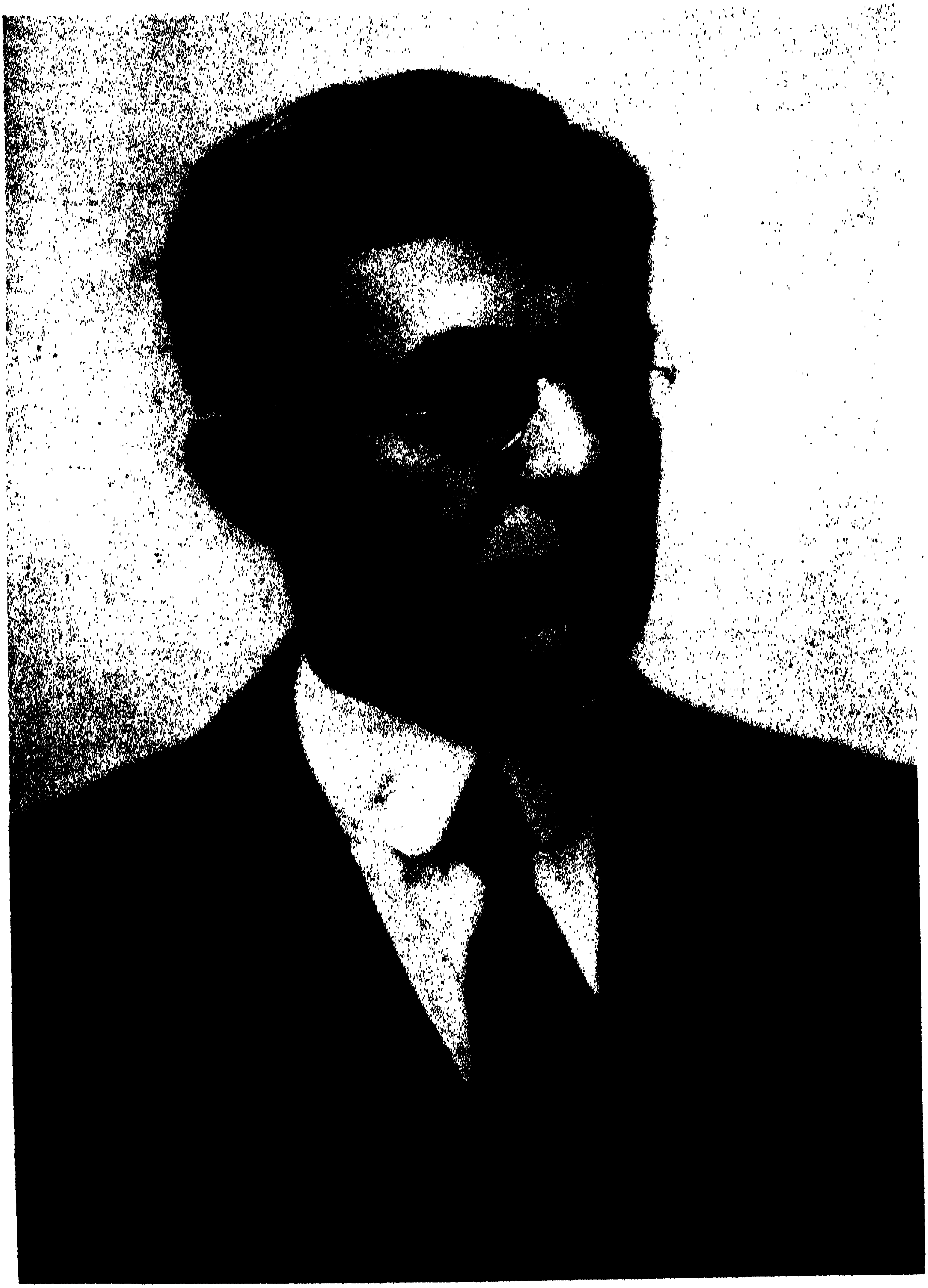
IRA B. HANSEN

[1] *Developmental Anatomy.* By L. B. Arey. Illustrated. xix + 612 pp. $6.75. 1940. W. B. Saunders Company.

"LIVING WAVE FUNCTIONS"

In Dr. Gamow's review of my book, "The Soul of the Universe," in the December number of SCIENTIFIC MONTHLY he writes that I have introduced the notion of "Immaterial Living Wave Functions," and then proceeds to show that wave functions have no physical counterpart in the external world. I have never in my book used the term "wave function," and obviously not the nonsensical term "living wave-functions." Instead I have used the terms fields of force, space-time structures, frequency patterns and wave systems as descriptive of *directly observable* space variations and time fluctuations of physical characteristics. If the variations at a particular place or places are rapid and fluctuating they can often be described in terms of waves or frequencies. For instance, the fluctuating electric field around many neurones in the brain can be described as "wave systems," a description which is entirely independent of any ideas about phase waves or wave functions. In describing the phenomena of life we must deal with the directly observable phenomena in space and time, without introducing any mathematical representation in multidimensional configuration space for which we obviously are not yet ready. Gamow's objection loses its force when we realize that we are dealing with structures in space and time which are, at least in principle, observable by our sense organs aided by suitable instruments.

GUSTAF STROMBERG



DR. IRVING LANGMUIR

THE PROGRESS OF SCIENCE

DR. IRVING LANGMUIR, NEWLY ELECTED PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

IRVING LANGMUIR was born in Brooklyn, New York, in 1881. His early school days were spent in Paris, France, and at the Chestnut Hill Academy, Philadelphia, Pennsylvania. After a course at Pratt Institute High School, he studied at the Columbia School of Mines, graduating in 1903 as a metallurgical engineer, and then studied physical chemistry with Nernst at Goettingen, Germany. Subsequently, he taught chemistry at Stevens Institute for three years. He joined the staff of the General Electric Research Laboratory in 1909, and since then has been continually active as a research scientist. During the past eight years he has been associate director.

He has been honored by degrees from many universities, including Oxford, Johns Hopkins, Harvard, Columbia and Princeton. For distinguished scientific services he has been awarded fifteen medals and other tokens. Among these are the Nobel Prize of the Swedish Academy of Science, in 1932, the John Scott Award of Philadelphia, and the Hughes, Perkin, Nichols, Chandler and William Gibbs medals.

His scientific contributions are best described in the 217 scientific papers which he has published. Because of the nature and number of those widely distributed contributions I can not review them adequately here. In choosing one line of his thoughts I might select a purely chemical one, but I should soon be at the end of ordinary vocabularies. Or I might take some attractive physical, electrical or illumination problem, but within each of those confines I should still feel that I had failed to picture him properly.

Integrating his work, I see that the scientific advances are made just at the extreme, almost invisible ends of paths of human interest, where part of the job consists of laying down hard new words as a sort of corduroy road.

As a start along one road you may enter the realm of Langmuir's radio tube contributions through an article by President Karl Compton, of the Massachusetts Institute of Technology, in a current issue of *Science*. But there were years of frontier-research involved, even there. Langmuir had to distinguish quantitatively the specific and different electrothermic emissions and study the migration rate of thoria, for example, in solid, heated tungsten, together with the surface films of chemically reduced thorium, before the countless types of radio tubes could be evolved. In addition, there were all sorts of studies of the electrons as they wandered about in vacua, influenced by different electrical forces. When mere traces of gases were present, entirely new phenomena were presented. Such words as "space charge," "bombardment," "positive ions" and "charged grid," brought out still more new names, such as pliotron, kenotron, thyratron, etc. Laid down at the right time and place, they have "made going easier" in many new territories.

While it seems to me that all his work is strongly tied together by his simple conceptions, it is still impossible for me to illustrate it. If I try to explain his contributions to "molecular films" I can not be clear enough, though he has paved the way in many American scientific circles by showing his fundamental monolayers. While these foreshadow infinite chemical research leading into processes of life and growth, living cell permeability, etc., the implications of such work may not be speculated upon here. He has directed his efforts so far as to deter-

mine form and structure, in parts or whole, or many sorts of organic molecules. This has included the immensely complex insulin. But I may confuse by even mentioning this.

Perhaps it is better to say that, just as Langmuir has contributed greatly to our elementary concepts of chemical valency and made us almost see the various kinds of bonds which express interatomic attractions and molecular coherence in such simple cases as helium and atomic hydrogen, and the "attractions" between hydrogen and chlorine in hydrochloric acid, so also in working with simple soap films he has opened up new conceptions of existing matter, such as two-dimensioned solids, liquids and even gases, together with their interreactions. And this he has done by simple means but with quantitative results.

Langmuir seems to love the simple—the simple, inquisitive youth, the simple, direct question and answer. His well-trained, questioning attitude makes him a fine, forward-seeing teacher of old and young. His physical energy and mental virility are very unusual. By his efforts he makes the subject of his interest important. Repeatedly investigating an apparently insignificant scientific point, he makes it most fundamentally significant. At the same time, as the resulting chips fly, he watches the direction of prevailing winds of utility or service.

Take, for example, that highly useful discovery, the gas-filled incandescent lamp. We see it every night, but how many understand it? How can the same size of glass bulb, with the same element, tungsten, have three times as much light-efficiency when, in place of a vacuum, it is filled with gas? Gas is obviously a greater heat dissipater than the vacuum, and the vacuum offers no obstruction to the light-emission of the filament. We had apparently almost exhausted all practical possibilities of making better vacua in our search for lamp improvements, but Langmuir first further improved even the methods. Then he carefully studied every imaginable thing left. What was happening to, with, through, by and/or among the adherent traces of persistent gas-residues? He experimented. After years of this, he learned the remarkably different effects of water vapor, nitrogen, oxygen and hydrogen where these elements were almost nonexistent. Space limits explanation here, but he learned about atomic or dissociated hydrogen, decomposed water, blackened and browned bulbs, rate of simple evaporation of the filament, and that each was dependent upon the others. Then he visualized the new advantage to be gained by coiling tungsten filaments in certain sized helices (instead of using simple "hairpins") and operating them in definite pressures of nonreacting gases. And so the new and better lamp.

The long lines of reasoning by simple, proved paths, but just beyond the former terminals, are to be seen in all his scientific work.

WILLIS R. WHITNEY

NOTABLE SCIENTIFIC PROGRAMS AT PHILADELPHIA

PROBABLY no other scientific meeting ever presented so great a variety of notable scientific programs as that of the American Association for the Advancement of Science at Philadelphia from December 27, 1940, to January 2, 1941, inclusive. In those six days 222 scientific sessions were held before which 2,164 addresses and papers were delivered or read.

Instead of attempting the impossible task of referring to all the programs of the meeting, a few will be enumerated, each of which was a joint discussion of some important field of science by a number of eminent specialists. The first on the list in the number of participants and perhaps in the importance of the subject was the symposium on "Alcoholism." There were 47 contributors to

this discussion which, in six half-day sessions and one evening session, considered the subject in (1) its physiological and chemical aspects, (2) its clinical aspects, (3) its neuropsychiatric features, (4) its treatment and prevention, (5) its social and legal problems (two sessions) and (6) a general session presided over by Dr. Thomas Parran, surgeon-general of the U. S. Public Health Service. The participants in this notable program were leading specialists in the problem of alcoholism from all sections of the United States. It is expected that this comprehensive and correlated group of papers will be published in one volume, probably by the American Association for the Advancement of Science.

Another program of similar scope and completeness was the symposium on "Human Malaria" in which there were 42 participants, including the foremost specialists in the field in this country. The malaria problem is of great importance in the southern states and the insular possessions. It is especially important at present because of the large number of army camps that are being established in the South in the national defense program and because of the large number of men who will be employed in constructing naval bases in the Caribbean and West Indies regions.

Not all the large programs, however, were on medical subjects. Three of an entirely different character were "A Scientific Basis for Ethics," "Science and Value" and "The Scientist and American Democracy." Since all three of these symposia are similar in that they are concerned with the significance of science in moral and social questions it has been suggested that the association publish them together in one volume.

Another distinguished program of a quite different type was organized in

AMERICAN ASSOCIATION BOOTHS AT THE SCIENCE EXHIBITION

TWO OF THE EIGHTY OR MORE EXHIBITS HOUSED IN CONVENTION HALL, SHOWING IN THE BACKGROUND A SERIES OF PORTRAITS AND LETTERS FROM PAST PRESIDENTS OF THE AMERICAN ASSOCIATION. THE PICTURE OF THE FIRST PRESIDENT, W. C. REDFIELD, CAN BE SEEN IN THE UPPER LEFT-HAND CORNER. MR. SAM WOODLEY, THE ASSISTANT SECRETARY, HAS COLLECTED A SET OF THESE PORTRAITS AND LETTERS—ONE EACH YEAR SINCE THE FOUNDING OF THE ASSOCIATION 92 YEARS AGO.

celebration of the centenary of the publication of one of the most influential books in the history of chemistry, namely, Liebig's "Organic Chemistry in the Applications to Agriculture and Physiology," the first edition of which appeared in 1840. The participants in this symposium discussed, with adequate references to the literature, the amazing and often quite unexpected developments of the regions which Liebig entered a century ago.

To mention a program at the opposite extreme of human interest, the American Philosophical Association presented a symposium on "The Problem of Religious Knowledge." And again, the geologists looked into the earth in their two sessions on "The Igneous Rocks of the Appalachian Mountains System," while the astronomers looked up to the stars in theirs on "Intrinsic Stellar Variation."

The few programs that have been mentioned illustrate the enormous diversity of the aspects of science. They are as varied as the interests of the human mind; indeed, they are more varied, for science is now involved in every human activity and is rapidly creating innumerable new interests—and problems. The rapid changes that are taking place in the world as a consequence of science are disturbing to many persons, especially to those gentle souls who find happiness in drifting with the tide. But reason and the whole history of the earth, and of the

THE SYMPHONY ORCHESTRA ABOUT TO PLAY FOR THE ASSOCIATION
SHOWING ONLY ABOUT HALF OF THE SWARTHMORE GROUP; DR. SWANN IS STANDING.

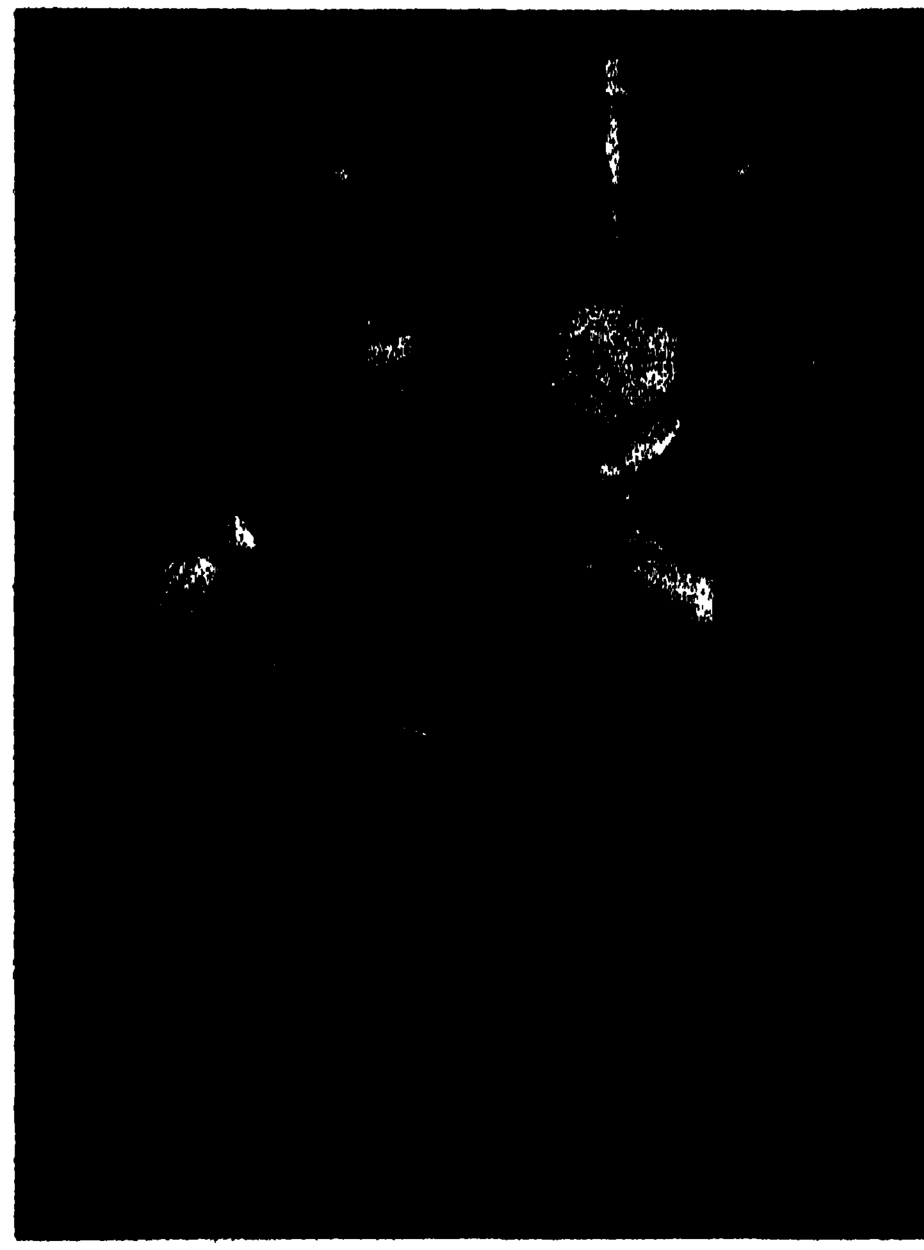
Naturally the world war stimulated the organization of certain programs, the most obvious being "Psychology and the National Emergency." One of the participants was Dr. Leonard Carmichael, president of Tufts College and chairman of the committee which is preparing, for national defense, an essentially complete roster of the tens of thousands of American scientists, together with their respective preparations, qualifications and preferences for service.

life on its surface, teach us that improvements come only with changes and that dinosaurian complacency with existing conditions leads only to stagnation and extinction. Those who participated in the programs that have been enumerated, and in many others, prefer to pursue the entrancing and adventurous paths of science.

The scientist, however, is not simply a rigid experimenter or a cold logical machine. Whatever rare qualities he may have while he is working in his own special field, he is nevertheless a human being and shares in the weakness of human beings. He also shares with artists, often to a very exceptional degree, an appreciation of and skill in various arts. Mathematicians and astronomers have long been noted for their taste for music. Of course not every mathematician has musical talent. Possibly the percentage of mathematicians who love music is not greater than that among other persons of similar culture. The tradition may have arisen because it seems incongruous to a non-mathematician that a mathematician should be interested in artistic things. There appears to be no claim that musicians as a class have exceptional mathematical ability.

Whatever the statistical facts may be, it is highly probable that scientists are at least as gifted in art as the average person. They must be, for science at its highest level is art. It produces esthetic effects similar to those produced by music, poetry and painting. The recently elected president of the association, Dr. Irving Langmuir, is an artist in everything he does. He listens to symphonies musicians never heard and sees rainbows that never appeared in the sky. In his work he builds beautiful structures that the language of ordinary mortals can not describe.

All I have said about scientists and music was illustrated at a tea for the



DR. SWANN PLAYING THE CELLO

EXECUTING MUSICAL ENTERTAINMENT

FROM LEFT TO RIGHT: J. STOGDELL STOKES, CHAIRMAN OF THE ENTERTAINMENT COMMITTEE FOR THE ASSOCIATION; DR. W. F. G. SWANN, DIRECTOR OF THE SWARTHMORE SYMPHONY ORCHESTRA, AND LUCIUS COLE, CONCERT MASTER.

members of the association provided by the local committee in Philadelphia. A great physicist, mathematician and scientist led the Swarthmore Symphony Orchestra of about seventy members in rendering a splendid program of classical music. This remarkable leader was W. F. G. Swann, director of the Bartol Research Laboratory. Concerning the composition of his orchestra, which was founded in 1936, he says:

"Our membership covers a very wide field of professional activities. Our First Bassoon, Dr. R. L. Spencer, is Dean of the College of Mechanical Engineering of the University of Delaware. He drives 30 miles each way for a rehearsal every Wednesday evening. Our Second Bassoon comes from a distance of 10 miles in the opposite direction. Our leading Doublebass, R. C. Disque, is Dean of Drexel Institute. We have among our organization ten engineers, two chemists, a physicist (not counting myself) two physicians, a dentist, etc. Our chief Cellist, Mr. Natcho Vasileff, is a chemist, and he adds to his accomplishments that of a composer; the Nocturne which we played at the American Association for the Advancement of Science Reception was composed by him and dedicated to me."

F. R. MOULTON,
Permanent Secretary

NUTRITION AND GROWTH OF PLANTS[1]

A CONCEPT at one time often held by students of plant nutrition was that the absorption of inorganic nutrients by roots is a process in which the roots play a passive role and main emphasis was placed on permeability factors. Some early studies in the California Agricultural Experiment Station on barley plants and later on cells of the fresh-water alga *Nitella*, from which latter vacuolar sap only slightly contaminated could be obtained, gave evidence that ions can be absorbed by plant cells against concentration or activity gradients, with the use of metabolic energy. With this interpretation in view, F. C. Steward conducted experiments of basic importance on potato tuber tissues, and the relation of aerobic metabolism to ion accumulation (movement and storage against a gradient) was demonstrated for these tissues.

DR. DENNIS ROBERT HOAGLAND

Of direct interest to the subject of the paper are the extensive studies of Hoagland and Broyer on the metabolic processes in root cells involved in the accumulation of inorganic solutes and also certain types of movement of these solutes from the roots to the upper parts of the plant. A technique was developed by which young barley plants produced root systems of extremely high capacity to accumulate mobile ions, *e.g.*, potassium, bromide and nitrate ions. In

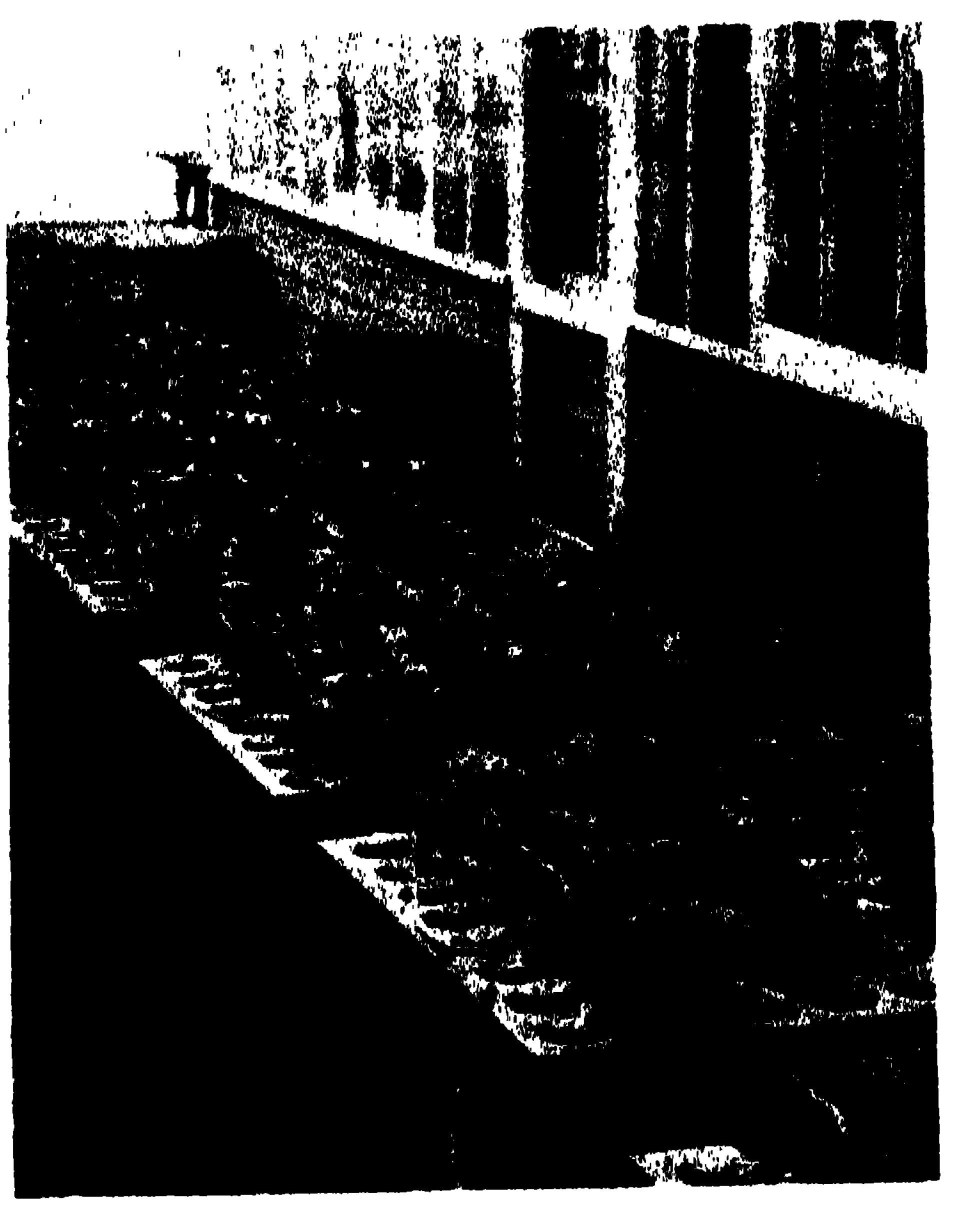
[1] Review of the paper entitled "Availability of Nutrients for Plant Growth with Special Reference to Physiological Aspects," presented by D. R. Hoagland and D. I. Arnon at the meetings of the American Association for the Advancement of Science, December, 1940.

many of the experiments some of the great complexities of the whole plant system were avoided by making observations on excised roots over brief experimental periods. In this way direct evidence was secured with reference to the effects on salt accumulation of oxygen, carbon dioxide, temperature, concentration of salt and hydrogen ion concentration in the external environment, and of available carbohydrate in the root cells. Briefly, the evidence led to the conclusion that the most rapid absorption of ions and their accumulation against gradients occurred as a result of protoplasmic activities reflected in aerobic respiration for which a supply of oxygen, sugar and presumably of certain growth substances are essential. Sugar and some other required organic constituents are, of course, normally derived from the photosynthesizing tissues of the plant. When other conditions do not limit, the temperature coefficient of the accumulation process is found to be high.

The efficiency of highly active roots in removing from a nutrient solution ions like potassium and nitrate is very high. In fact, concentrations may sometimes be reduced almost to zero in the solution at the same time that the sap from the roots has high concentrations of the ions absorbed. Reciprocal relations of root and shoot in the process of nutrient intake by the plant may be more clearly envisaged on the basis of these and other researches along similar lines. The remarkably rapid and selective absorption of certain ions from very dilute solutions is of great interest in the study of availability of nutrients in soils. Experiments by Arnon and his associates using other types of technique also developed evidence of the importance of metabolic relations in the study of problems of general plant nutrition, including researches on nitrate and ammonium salts as sources of nitrogen in the culture medium.

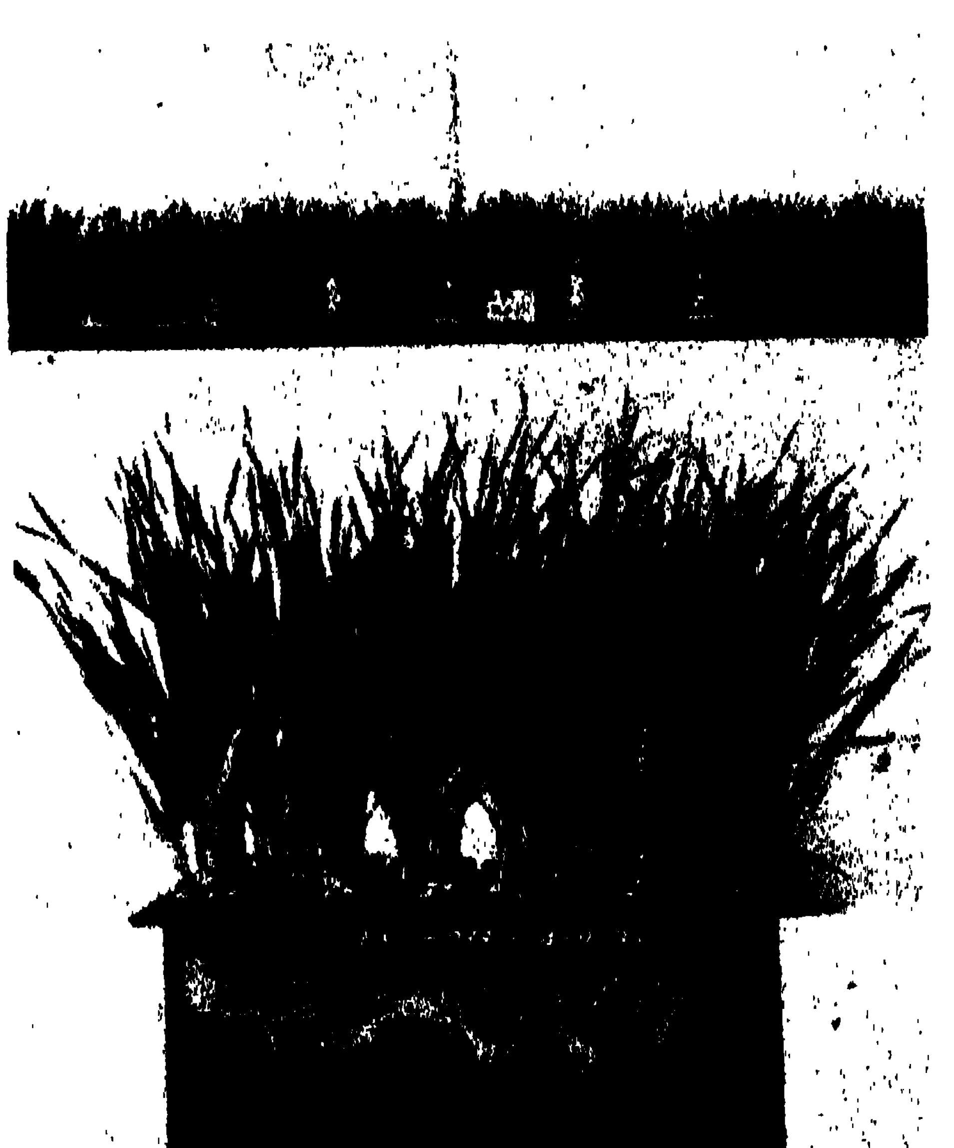
Since there is naturally a limit to the salt-holding capacity of root cells, the absorption of ions by intact plants over any extended period depends not only on the intake factors already described but also on the upward movement or transport of solutes to the shoot. Experiments over limited intervals of time on young barley plants with very active root systems showed that this movement can take place about as readily in the dark as in the light. Excellent growth of such young plants was possible even when nutrients were supplied only during night periods. Absorption of nutrients was approximately the same for 12-hour periods including either day or night. In other words, the plants were at work 24 hours a day when nutrients were made continuously available and the metabolic activities of the roots maintained. However, root pressure conditions are important in these cases, when transpiration is reduced. With older and larger plants the evidence is that continued absorption of ions may depend, indirectly, on transpiration as a

DR. D. I. ARNON



WATER CULTURE EQUIPMENT

FOR STUDY OF NUTRITION OF LETTUCE PLANTS WITH REFERENCE TO AERATION OF ROOTS AND PROPERTIES OF NUTRIENT SOLUTIONS.



YOUNG BARLEY PLANTS

GROWN BY TECHNIQUE ADAPTED TO PRODUCTION OF ROOTS OF HIGH CAPACITY TO ABSORB AND ACCUMULATE CERTAIN IONS.

means of accelerating upward movement of solutes. But even in transpiring plants some experiments suggest that cell activities are involved in the movement of solutes into the conducting tissues. The writers of the paper, while stressing the significance of active absorption for normal plant growth, also call attention to the possibility that under the influence of transpiration, another type of absorption and upward movement of solutes may take place through inactive or injured roots, and this is illustrated by experiments in which the culture solutions contained sodium salts in increasing concentration up to a point of injury.

In investigations of the absorption of ions and their movement in the plant it is frequently desirable to study established plants over short periods during which the plant system as a whole undergoes as little alteration as possible. The problem then may arise as to technique by which small amounts of elements absorbed and distributed in the plant during the experimental period may be determined. Special difficulties must be faced when it is decided to study the same elements that are already present in the plant at the beginning of the experiment. Fortunately these difficulties can often be surmounted by the aid of the new tool of radioactive isotopes, and various workers in the laboratory have employed radioactive potassium, phosphorus, sodium, bromine and rubidium in the further investigation of problems of absorption and movement of inorganic solutes in the plant.

Jenny and Overstreet in this laboratory have found great value in the radioactive isotopes as a means of study in their attack on the problem of contact intake of ions by plant roots. Evidence was obtained that plants may absorb some ions by direct contact exchange of ions between roots and soil colloids as well as from the soil solution. The general technique already referred to for

making observations on actively absorbing roots was utilized in the researches on absorption of ions from suspensions of soil colloids.

Accumulation of solutes may occur, not only in root cells, but likewise in other parts of the plant. Arnon and Stout carried through a series of experiments on fruiting tomato plants in which they followed the movement of radioactive phosphate added to the nutrient solution when the plants had reached the desired stage of development. The younger and most rapidly growing fruits had the greatest ability to accumulate the newly supplied phosphate. Its distribution in fruit or foliage was demonstrated in graphic manner by making radiographs of the tissues. By employing radioactive isotopes, Stout, Hoagland and Broyer, and Bennett have gained an especially definite kind of evidence on the old problem of which plant tissues are mainly responsible for the upward movement of salts and of the relation of transpiration to this movement.

The authors devote part of their paper to a discussion of the general significance of physiological investigations for the practical problems of plant nutrition. They cite their experiments to compare the growth of plants in soil, sand and water culture media as bearing on the importance of effects of aeration of the root medium. It is pointed out also that aside from direct effects of oxygen on the process of ion absorption, aeration of the soil may profoundly influence the growth of roots and the development of root surface. Under favorable conditions this surface may be enormous in extent and thus innumerable contacts established with soil particles. This exploration of soil by roots and all the factors that influence it, including the internal metabolism of the plant and the climatic conditions, as well as physical and chemical

CHAMBER FOR CONTROLLED GROWING CONDITIONS

PLANTS UNDER CONTROLLED CONDITIONS OF LIGHT, TEMPERATURE, HUMIDITY AND NUTRIENT SOLUTION, IN SOME OF THE STUDIES ON ABSORPTION AND TRANSPORT OF NUTRIENT IONS. THIS ILLUSTRATION SHOWS TOMATO PLANTS USED IN A PRELIMINARY EXPERIMENT OF ANOTHER TYPE.

conditions in the soil, must be of great consequence for an understanding of availability of nutrients.

Specific questions of potassium and phosphate absorption by plants under different soil conditions are discussed from the physiological point of view. Some attention is also given to the micro nutrient elements (elements effective in plant growth in very minute amounts). The climatic influence affecting the requirement or absorption of zinc by plants is cited as an example of a physiological interrelation of soil and plant.

This paper was written as a contribution to a symposium dealing with the general subject of absorption of nutrient ions by plants and their availability in soils for plant growth. The field was broad and the writers considered not only their own investigations, but also those of other workers in the University of California Laboratory of Plant Nutrition who have dealt in recent years with physiological aspects of the general problem under review. The illuminating results obtained by Professor Hoagland and other workers in the laboratory have demonstrated that the plant correlates a multiplicity of functions to acquire from the environment the necessary nutrients and to distribute them to the various centers of activity.

H. S. Reed

RAYMOND PEARL, 1879–1940[1]

In the death of Raymond Pearl on November 17, 1940, biology loses one of its outstanding figures. He was born at Farmington, New Hampshire, on June 3, 1879. At Dartmouth College he studied biology under William Patten and H. S. Jennings. On his graduation in 1899 he was appointed assistant in zoology at the University of Michigan, where he received the degree of doctor of philosophy in 1902.

In his memorial of Karl Pearson, Pearl has told how Pearson's "The chances of death" stirred his undergraduate imagination and enthusiasm. "It was alive, hearty, vigorous. It was about a lot of things you could do something about. It inspired curiosity and action, rather than awe. To a callow budding biologist, very young and very ignorant, it opened enchanting vistas of possibilities in biological thinking and research before undreamed of." It is little wonder then that the years 1905 and 1906 found Pearl a student in Pearson's biometric laboratory at University College, London. Although the two did not always agree on biologic matters, Pearson's influence on Pearl was strong.

[1] Submitted for publication on December 30, 1940.

From 1907 to 1918 Pearl was head of the department of biology of the Maine Agricultural Experiment Station. During this period his work dealt largely with the biology of the domestic animals, notable researches being on the inheritance of egg production and of milk production.

On the entry of the United States into the First World War Pearl became chief of the statistical division of the United States Food Administration. His studies on the relation of food supply to population are presented in "The nation's food."

From 1918 until his death Pearl was on the faculty of the Johns Hopkins University, first as professor of biometry and vital statistics in the School of Hygiene and Public Health, then from 1925 to 1930 as director of the Institute for Biological Research, and finally as professor of biology in the School of Hygiene. Although much of his attention was given to research, his influence as a teacher was felt by many of the younger generation of statisticians. Most of Pearl's studies at Johns Hopkins centered around the biology of population growth and of the factors that enter into it, such as birth rates and death

RAYMOND PEARL

rates. In 1798 Malthus had emphasized the checks to the growth of population, but the rapid expansion of industry during the nineteenth century had led most students of the subject to disregard them. Pearl was, so far as we know, the first writer of recent times to re-emphasize that there must be a finite upper limit to any population. This was one of the postulates from which Pearl and Reed derived the logistic curve, which, it was later found, had been proposed nearly three quarters of a century before by the Belgian mathematician, Verhulst. This curve fits closely to the growth of the populations of a large number of countries. It also describes the growth of experimental populations of fruit-flies.

A related subject which Pearl also investigated by the experimental method was the inheritance of the duration of life. Different lines of descent of fruit-flies, he found, had different distributions of longevity and when a fly of a long-lived line was mated with one of a short-lived line the duration of life of their descendants followed the ordinary course of mendelian inheritance. Naturally one can not investigate the inheritance of longevity in man by the experimental method, but it has been found by the statistical method that in man, as in the fruit-fly, inheritance is an important factor in determining the duration of life.

Connected with these investigations of the factors that affect death were the investigations of the factors that affect birth described in "The natural history of population." These included the analysis, not only of official vital statistics on birth rates, but also of information about the reproductive histories of a large sample of women, obtained from them while they were patients in the obstetric services of hospitals.

Besides these researches of his own in the field that unites biology to the social sciences, Pearl found time to aid in the advancement of science both by participation in the direction of scientific societies and by the editing of scientific journals. He was the leading spirit in the formation of the International Union for the Scientific Investigation of Population Problems, of which he was president from 1928 to 1930. He was also at various times president of the American Association of Physical Anthropologists, the American Society of Zoologists, the American Society of Naturalists and the American Statistical Association and a member of the council of the National Academy of Sciences. He was the founder and the editor until his death of *The Quarterly Review of Biology* and of *Human Biology*.

Pearl once commented on the great similarity between original creative effort in art and in science. The artistic side of his own nature is shown, not only by his delight in music, but also by his literary skill in presenting his scientific results. Certainly no one could apply to his writings his criticism that "scientific journals are, at the best, occasionally dull, and, at the worst, always so."

Another token of his artistic sensibility was his care in the planning of head-pieces and tailpieces for *The Quarterly Review of Biology* and *Human Biology*. The bowman who forms the leitmotiv of the latter was taken from the wall decoration of a paleolithic rock shelter. The prehistoric artist, who was born before the days of Queen Victoria, had represented the bowman with all his members. When the design was submitted to the publisher of *Human Biology*, he protested that it would offend the postal authorities. The bowman was therefore emasculated and the putative sensibilities of the postal authorities were spared.

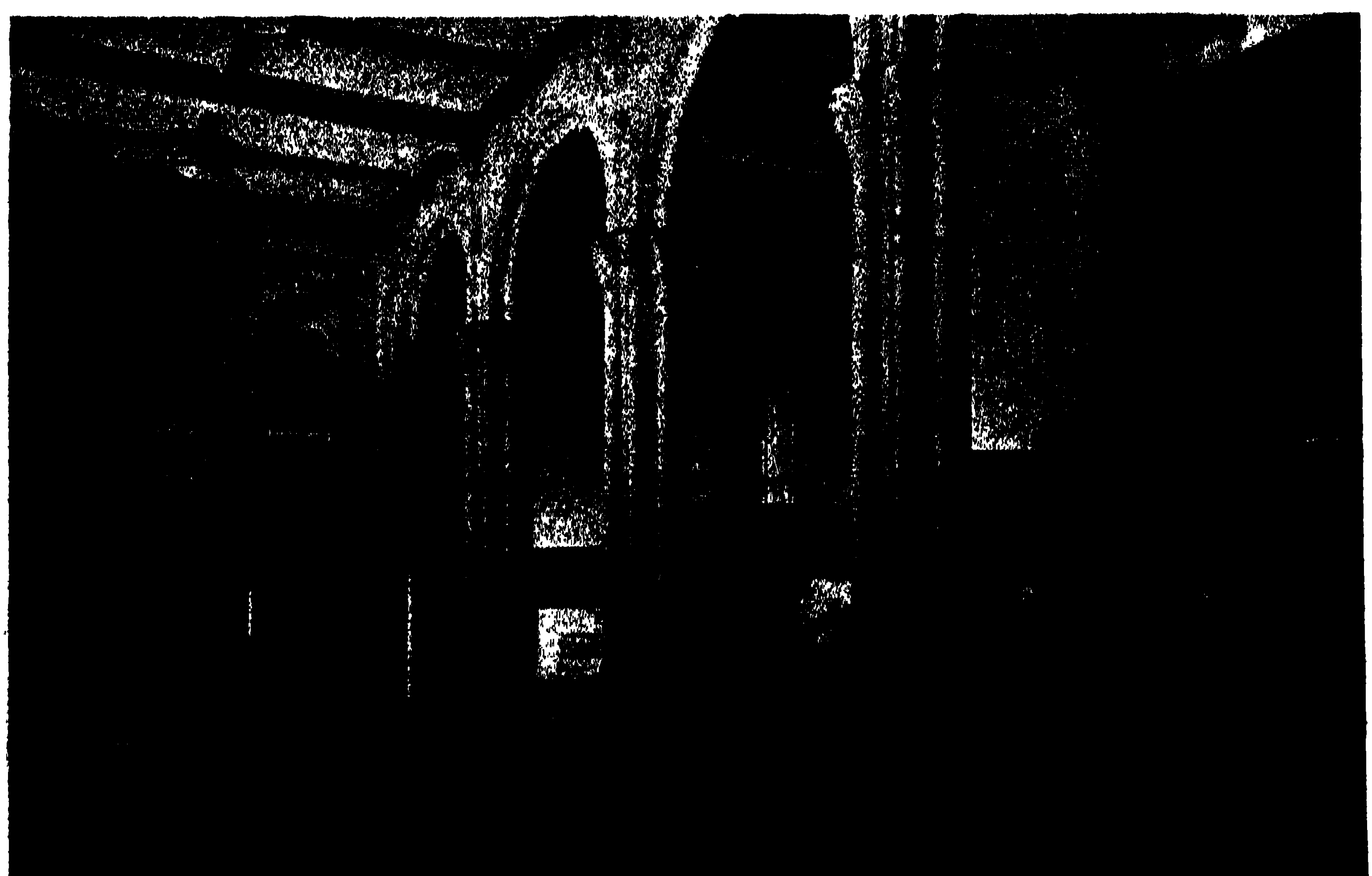
JOHN R. MINER
JOSEPH BERKSON

NEW "INDEX EXHIBIT" AT THE SMITHSONIAN INSTITUTION

On Monday, January 20, after six months behind closed doors, the Smithsonian Institution in Washington opened to the public a unique and fascinating exhibit designed to clarify for its millions of visitors the diverse activities and affiliations of the institution. For 95 years the Smithsonian in its laboratories and study rooms has delved into the mysteries of many branches of science; hundreds of its expeditions have gone out to the far corners of the earth in search of new facts and materials; its investigations have been recorded on nearly 500,000 pages of print, making up thousands of volumes of basic scientific knowledge that can be found in most of the world's large libraries. As the years have rolled by and our country has grown in size and grandeur, so too has the Smithsonian grown and expanded its sphere of usefulness. Its fields of activity have multiplied and its physical equipment of buildings for research and exhibition have increased in number.

For the benefit of visitors who are puzzled by the apparent heterogeneity of the institution's activities, the new exhibit is planned so as to classify these activities under major headings, briefly defined. The great Gothic hall of the institution, 123 feet long by 50 feet wide, is divided into 12 alcoves, each with its appropriate heading. Each has a central theme, intended to visualize in some striking way the significance of the particular activity portrayed.

As the visitor enters the hall, he sees on the right a quadrant whereon are listed the subjects of Smithsonian activities in the order in which they are exhibited; also, a list of the eight methods used by the institution for the diffusion of knowledge. On this first quadrant is a large sign telling him that to see the



ONE CORNER OF THE EXHIBITION HALL AT THE SMITHSONIAN INSTITUTION
SHOWING SECTIONS OF THREE OF THE EXHIBITS.

SMITHSONIAN INSTITUTION BUILDING
WHERE THE NEW EXHIBITION IS LOCATED.

exhibit in logical order he should begin with the adjoining alcove and proceed completely around the hall.

The first exhibit is that of astronomy, and this is followed in turn around the hall by geology, biology, radiation and organisms, National Zoological Park, history, physical anthropology, cultural anthropology, engineering and industries, and art. The final quadrant—the last thing the visitor will see as he leaves the hall—is devoted to a pictorial explanation of the organization and branches of the Smithsonian, so that the visitor will leave with an understanding of the present rather complex set-up of the institution.

A separate room is devoted to exemplifying the Smithsonian's methods of diffusing knowledge, the second major objective of the institution.

The theme of the entire exhibit is simplicity. A multiplicity of objects is carefully avoided, and all labels are brief and plainly worded. The strictly enforced aim is to give a quick, easily comprehended bird's-eye view of Smithsonian activities and organization.

WEBSTER TRUE,
Editor

THE SCIENTIFIC MONTHLY

MARCH, 1941

POST-NATAL DEVELOPMENT OF THE HEAD

By Dr. C. B. DAVENPORT
COLD SPRING HARBOR, N. Y.

THE development of the child in the uterus has long been made the subject of careful study. Probably a scientific curiosity has led many to study a stage in human development so hidden from ordinary observation. But from birth on the development of the child is open to the observation of all. It has been taken for granted. Its changes have not, until recently, been analytically investigated. Now a beginning has been made.

The proportions of the new-born babe, with its big head and short extremities, are very obviously different from those of the adult; but again these differences, observed for millennia, have only recently been measured. As for the changes at adolescence, though noted by the mother whose son outgrows his clothes before they are worn out, their analysis has hardly begun. Precise measurement of all these changes is called for.

The earliest measurements on child growth were apparently made on the tacit assumption that there was a more or less uniform object—"the child." This child underwent changes in size and development. But since "the child" was subject to accidental fluctuation in development, the proper picture of the way this "child" grows is given not by measurement of one child, but by measuring many children, massing and averaging the measurements. Even this procedure met with the difficulty of the proper way to mass data. Commonly the age is taken as the basis of grouping; but it has been properly urged that children differ so in speed of growth that stage of development is to be considered in massing. But such a procedure meets with even greater difficulties. Gradually the conviction has dawned that "the child" as revealed by mass statistics of any sort is a bit of fiction. Reality is found only in the growth changes of individual children: Mary, John, Greta, Hans, Giovanna, Antonio, Rose and Isidore.

As a part of a program to learn how individual children grow and especially how their proportions change the measurements made upon the heads of a large number of children followed for a number of years (in extreme cases during 14 years) were assembled and generalizations drawn from them. The American Philosophical Society undertook to publish the results. Some of the findings may have a general interest and consequently are recounted here.

The human head is an extraordinary organ both on account of its relatively great size and because it encloses man's relatively large brain and carries his relatively reduced face. At the end of the first quarter of intrauterine development bony plates begin to be found around the brain, but these are not united until some months after birth.

This delay in ossification is a clear adaptation to the birth process in which, of all parts of the child, the head offers the greatest difficulties. It is the great size of the head of the new-born that offers such difficulties. At birth the head has acquired nearly 66 per cent. of its adult size; by the end of the sixth post-natal month 80 per cent.; while at birth stature is only 40 per cent. of completion. Growth of the head, especially of the brain case, is the most precocious of all parts of the body. Why is this? Of course we don't know all the circumstances that have led to the great cranial precocity of the new-born. But we can see some reasons for it; and these are mostly reasons why the brain should be so precocious. Indeed, at birth it constitutes about 12 per cent. of the weight of the body, while in the adult it constitutes only about 2 per cent. It seems probable that one reason is that the brain must be ready to perform a large part of its functions at birth. To be sure, the average baby at birth is not able to be as active as a new-born colt. In its helplessness it is more like a puppy. But its senses become quickly functional. It looks at a bright light shortly after birth. It may react to sounds within a few days after birth. The sense of taste is usually well developed. The nipple is clearly felt. The neuro-muscular system is developed enough to function in suckling and in the movement of the extremities. The latter movements, indeed, precede birth for some weeks. Within limits the neonate is a going concern.

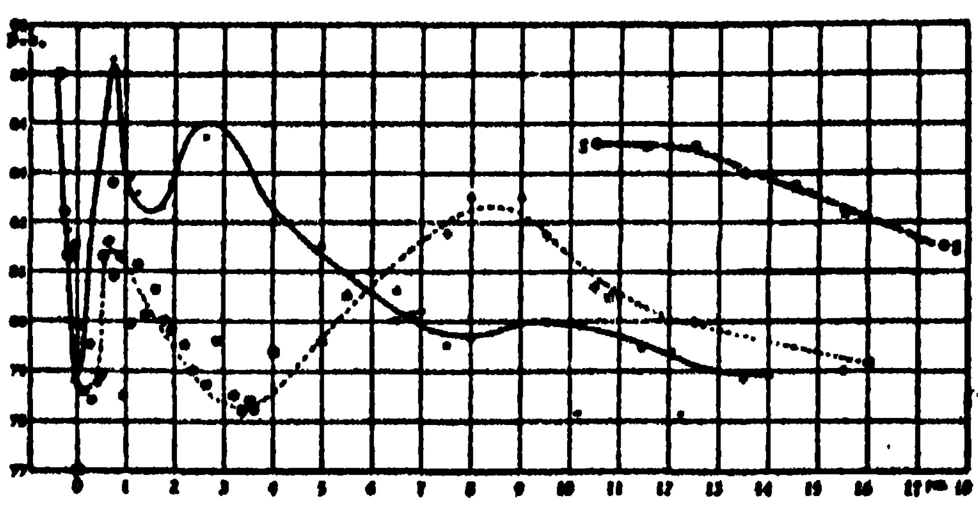


FIG. 1. CHANGE WITH AGE OF INDEX

CURVES OF MEAN CHANGE WITH AGE OF THE CEPHALIC INDEX OF NORMAL WHITE NORDIC CHILDREN. ABSCISSAE: AGE IN YEARS. "O," BIRTH. ORDINATES: THE CEPHALIC INDEX, OR THE PERCENTAGE RATIO OF HEAD WIDTH/HEAD LENGTH. SOLID LINE, BOYS; BROKEN LINE, GIRLS; DOTS, MEANS OF BABY BOYS, BIRTH TO 3½ YEARS; CIRCLES, BABY GIRLS; × AND + MALE AND FEMALE OLDER CHILDERN. S, CHANGE OF INDEX WITH AGE OF FEHMARANER (SALLER).

Another reason why the brain is so large at birth may be because it has so much to do in the course of development to be ready for more complicated mental function such as speech and all the play reactions. It is estimated that there are 13,500,000,000 neurons (or nerve cells and their fibrous prolongations) in the human cerebral cortex. Then there are additional hundreds of millions in the cerebellum. In order that these should be pretty generally available before the child begins to walk at one year the development of the brain has to begin early and proceed rapidly—more rapidly than all other, less complex, organs.

The brain case not only enlarges in the first few months after birth, but it changes shape—above all in the first few days after birth. This change of shape is well shown by changes in the cephalic index, which gives the relation of head width, above the ears, to the head length. On the average before birth the index decreases until at birth the head is relatively elongated (dolichocephalic) apparently in adjustment to the space in the uterus. During the days of adjustment to and accomplishment of the birth process the head is rendered temporarily more brachycephalic as that shape fits better the pelvic canal. For the next few months the head elongates again but subsequently tends, on the average, to become relatively wider (Fig. 1).

The brain case is, indeed, not the rigid thing that the dried skull is. During infancy and childhood it is responsive to a changing environment. If the infant lies with the back of the head sunk

in a soft pillow, or if it is fastened to a board with the occiput resting on it the head becomes flattened behind. But if it lies on the side of the head it tends to become longheaded. This has been demonstrated experimentally. However, the difference thus induced becomes mostly smoothed out in later childhood unless the pressure has been too prolonged or too rigid, as happens in flat-headed Indians and Armenians. The plasticity of the skull is shown by the fact that the distance above the ears decreases when the child begins to walk, owing to the pull of gravity, and when a boy jumps from the shed roof to the floor the form of the head may be temporarily changed by the blow received at the base of the brain case. In fact, all the way to puberty the boy's skull tends to flatten more and more at its base, doubtless due to gravity (Fig. 2).

Even in the early teens of children, after the bones of their skulls have come more or less in contact, the sides of the skull changes shape owing to the circumstance that the bone that carries the internal ear grows faster in front and below than in other radii so that the ear opening tends to move backward and upward. By this process the part of the head behind the ear ceases to grow as fast as it otherwise would (Fig. 3).

The form of the brain case is, as is generally known, very different in different races of the Old World. Thus the Negroes have a relatively long skull. The inhabitants of southern Germany and Switzerland have short skulls. These differences are apparently due to different methods of growth of the brain itself around which the case is molded. The brain case undergoes great modifications from the standard owing to defects in the growth process of the brain and bones of the skull. Thus in hydrocephalics (with water on the brain) the skull is greatly enlarged, whereas in microcephalics the brain case remains

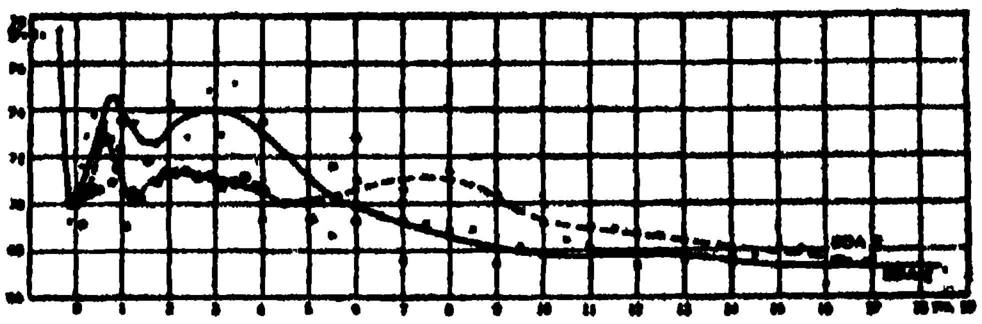


FIG. 2. HEAD HEIGHT AND LENGTH

CURVES OF MEAN CHANGE WITH AGE OF THE PERCENTAGE RATIO OF SUPRAAURICULAR HEAD HEIGHT TO MAXIMUM HEAD LENGTH, NORMAL WHITE NORDIC CHILDREN. SOLID LINE, BOYS; BROKEN LINE, GIRLS. SYMBOLS AS IN FIG. 1.

like that of an infant. The microcephalic condition has been assumed to be due to the early union of the sutures of the bones that make up the brain case, but that is certainly not the whole story, for in a certain microcephalic boy the dimensions of the brain case were still increasing during puberty, at a much faster rate than the skull dimensions of a standard child (Fig. 4). This shows clearly that even after union of the sutures the brain case can enlarge through an increase in the substance of the bones elsewhere than along their margins.

The capacity of the bones of the skull to undergo profound transformations in their very substance is well seen in the formation of the frontal sinus, the large spaces both above the root of the nose and at the level of the eyebrows. The frontal sinus varies greatly in development from nothing at all to a large, bladder-like space. Its presence becomes painfully known when the lining membrane becomes infected and drainage through the nasal sinuses is obstructed.

The sinus begins to form during early childhood in the interior of the frontal bone in the layer of spongy bone that lies between the two dense surfaces. As the pocket from the nasal cavity penetrates into this spongy tissue the two dense layers may separate widely from each other to the extent of nearly a half

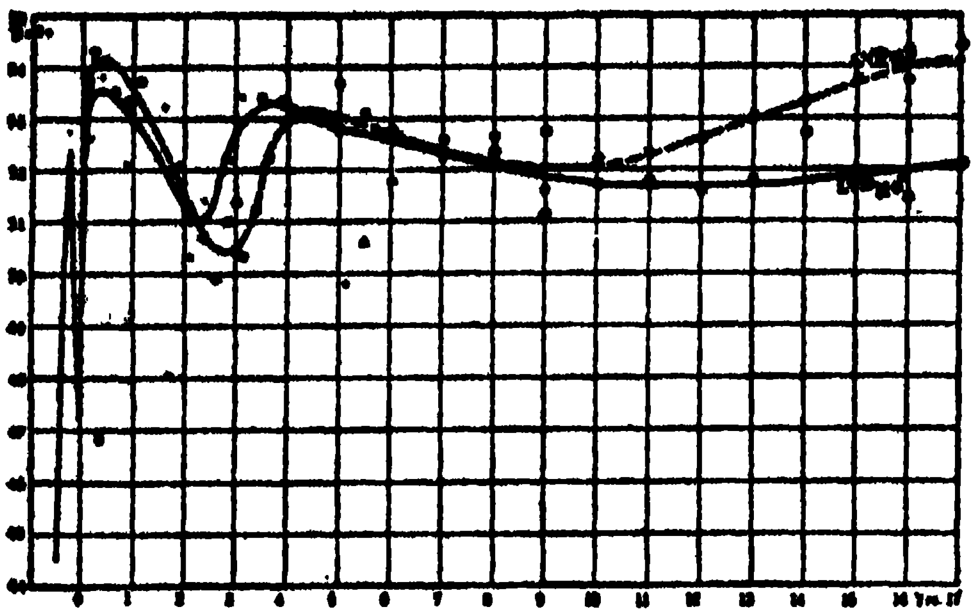


FIG. 3. EAR OPENINGS

CURVES OF MEAN CHANGE WITH AGE OF THE POST-AURICULAR TO MAXIMUM HEAD LENGTH. THIS SHOWS THAT THE PART OF THE SKULL BEHIND THE EARS BECOMES RELATIVELY LESS FROM 4 TO 10 OR 12 YEARS. EVEN LATER THE EAR OPENINGS TEND TO MOVE BACKWARD SO THAT THE POST-AURICULAR INCREASE IS LESS THAN IT WOULD OTHERWISE BE.

an inch. The whole frontal bone is remodeled during this development of the frontal sinus. The frontal sinus seems to have no important function in man. There is nothing gained by its presence, so that children who have no frontal sinus seem to function quite as normally as those who have. It is probably a rudimentary organ which was useful in the anthropoid apes with their heavy skull bones, just as the sinuses in the head of the elephant makes its weight tolerable; but in man where the skull is balanced on the end of the vertebral axis the weight of the skull becomes a relatively unimportant matter.

In the development of the head the changes in the face are very marked; indeed, one of the principal differences between the heads of the anthropoid apes and man is the great reduction of the face in the latter. In the baby at birth the face is, indeed, a very small part of the head, as it is also in newly born anthropoid apes. But whereas in the young ape the jaws develop rapidly and to great extent, in the child they remain always relatively reduced. The nose is perhaps the most prominent part of the face of the child. This develops slowly and reaches a degree of protrusion not attained in the apes.

Changes in the form of the face are largely due to the development of the jaws as the teeth are successively produced in them. Especially as the permanent dentition becomes functional and the three molars are formed the jaws begin to move forward. At the same time the great development of the maxillary sinus pushes forward still more the upper jaw to keep up with the growth of the lower jaw. Perfect occlusion of the jaws requires a harmony in the development of these two independent regions. It is perhaps not strange that we so frequently find a lack of harmony in people, with lower jaws receding or sometimes protruding, as is most strikingly seen in the bulldog.

Of the facial features one of the most striking is the pair of eyes. The human eyes have undergone a great change in position from that of very remote ances-

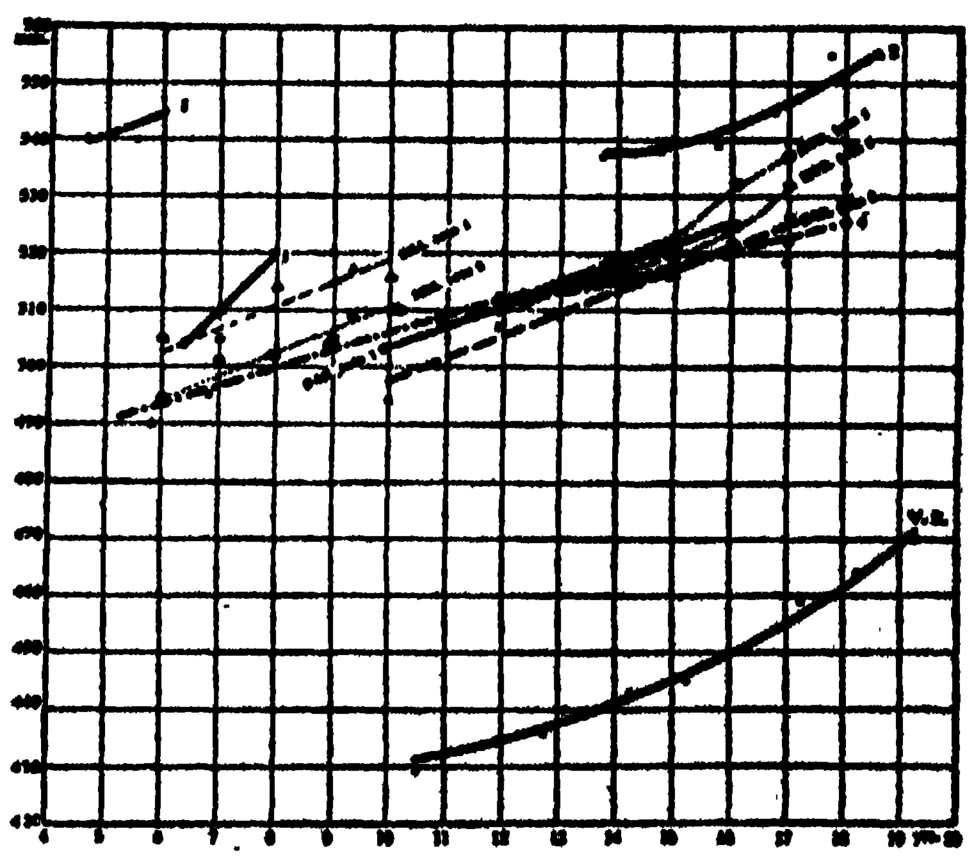


FIG. 4. GROWTH OF HEAD GIRTH

INDIVIDUAL CURVES OF GROWTH OF HEAD GIRTH OF TWINS AND SOME SPECIAL CASES. THE CURVES OF THE TWINS LIE MOSTLY CLOSE TOGETHER. CURVES 1, 2, 3 ARE OF CRETINS (LARGE HEADS). V.R. IS THE CURVE OF A MICROCEPHALIC. ITS SLOPE OF INCREASE IS AT 17–19 YEARS EVEN GREATER THAN THAT OF THE NORMAL CHILDREN.

tors. The eyes were originally paired organs as we see in fishes and even in the lower mammals, like horses. During human ontogenetic development the eyes begin as organs on the side of the head and gradually move to a position such that they look forward. This process is not completed at birth. The angle subtended by the optic nerves passing from the brain to the two orbits continues to diminish to puberty. This result is due to the interaction of two growth processes, one of which brings about the enlargement of the face as a whole and specifically in the transverse diameter and the other a tendency of the orbital angle to diminish. The first process tends to separate the eyes, the latter to bring them together. The approximation of the eyes is brought about in two ways. First, by the elevation of the root of the nose the skin is pulled away from the inner angles of the eyes. This happens in the case of European children, but in the case of the eastern Asiatics, where the root of the nose is shallow, a fold of skin persistently covers the inner angle of the eye. The second process affects the nasal and orbital bones, also partly in consequence of the reconstruction of the root of the nose. Thus the eyes, while separating as the head grows, separate less than the rest of the face and so the angle of divergence is reduced. Thus in a baby who was measured at 145 days after birth and again at 711 days the interorbital angle was reduced from 55° to 48° (Fig. 5).

Changes such as appear in the external dimensions of the skull case and the face are appearing also in the internal structure of the skull. Thus the pituitary body lies near the center of the head in the middle plane. It is largely imbedded in the sphenoid bone, one of the hardest bones in the body, and it is partly encapsuled by a bony wall. The size of this capsule (called the sella turcica) is very variable, being twice

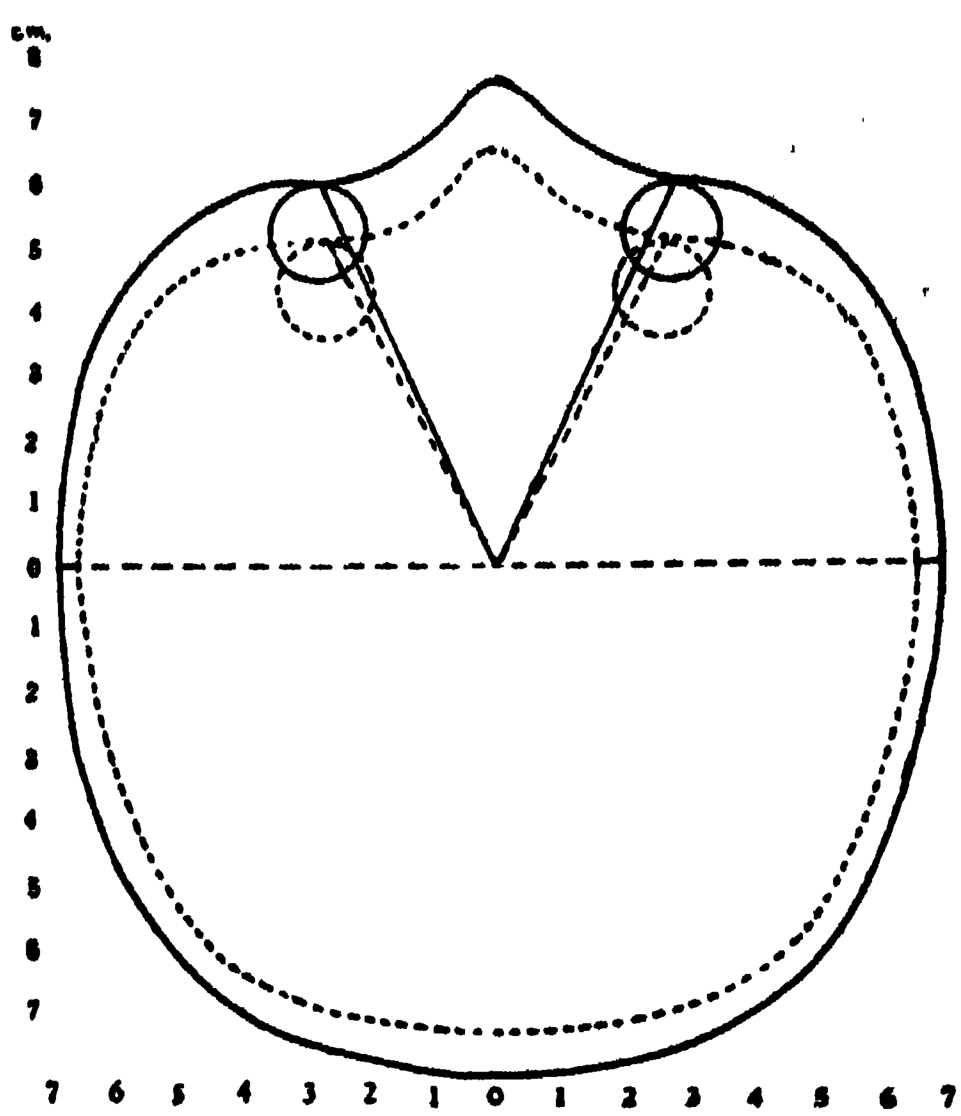


FIG. 5. HORIZONTAL SECTIONS OF HEAD

CONSTRUCTIVE OUTLINES OF HORIZONTAL SECTIONS OF HEAD OF A BABY BOY, AT THE AGE OF 145 DAYS - - - - - -, AND 711 DAYS (1 YR. 11½ MOS.) ————. THIS DISTANCE FROM INTERTRAGIAL LINE TO ORBIT IS DIRECTLY MEASURED OR COMPUTED FROM ADJACENT MEASUREMENTS. INTERPUPILLARY DISTANCE IS MEASURED (HALF THE SUM OF DISTANCES BETWEEN OUTER AND INNER ANGLES OF PALPEBRAL SLITS). THE TANGENT OF ½ INTERPUPILLARY DISTANCE DIVIDED BY TRAGION TO ORBIT IS FOUND AND DOUBLED. THE ANGLE AT 145 DAYS IS 55°.4; AT 711 DAYS 48°.8. FROM A SERIES OF MEASUREMENTS AT INTERMEDIATE AGES ASSURANCE IS GAINED THAT THE DIFFERENCE IS NOT DUE MERELY TO TECHNICAL ACCIDENTS. REDUCED TO 44 PER CENT. OF NATURAL SIZE.

as great in some children as others. This variation in size of the sella is associated with variation in size of the pituitary body. This pituitary body yields hormones of very great importance for the normal development of the child. However, the size of the pituitary body is probably not more important than the quality of the secretions which it produces so that the correlation between size of the pituitary body and the size of the body as a whole is not very large.

Now studies of the sella turcica in individual children repeated during a

number of years in the pre-, middle-, and post-adolescent periods, show that the volume of the size of the sella turcica may change regularly, generally increasing, with the growth of the body as a whole. However, in some cases the size of the sella turcica may actually diminish so that there is a readjustment of the hard bone in that the sella contracts to constitute a better fit of the shifting size of the pituitary body. It is well known, on the other hand, that the pituitary body may become enormously enlarged by the formation of a tumor in it, and under those circumstances the sella turcica becomes enlarged to meet the changes in size of the delicate pituitary body.

All these observations on the development of the head point to one conclusion, that there is first of all a set of internal directing forces in the growth of the brain and all the bones and other tissues of the head. These are the genetical factors. These developmental growth processes are, however, constantly affected by environmental conditions so that the growth may be modified by these changing conditions. Throughout development the living bones show themselves very plastic and able to reconstruct themselves as conditions demand, and the individual bone will adjust itself to the growth of adjacent bones and other tissues. The bones even respond to the pull of muscles and are largely molded by such pulls.

During the early stages of development the internal processes in the development of the head of the child show themselves to be much the same as the early processes in the head of the anthropoid apes. As later developmental processes appear the development of the skull leaves the ancestral path and strikes out in new lines, thus establishing the particular form of the human head. The path along which the human head develops even in its later stages is not a single one, however, as there are marked differences associated with sex, race, general physical and mental development and with varying functioning of endocrine glands and other growth-modifying processes. The whole study brings out clearly the fact that birth is only an incident in the development of the human being and that the post-natal changes which have been hitherto so much neglected are as real and in many cases as profound as some of the prenatal ones.

THE DISTRIBUTION OF HUMAN GENES

By Dr. HERLUF H. STRANDSKOV
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INTRODUCTION

MAN is an extremely variable species. He ranges from one who is short to one who is tall, from one who is white to one who is black, from one who is color-blind to one who has normal color vision. This list of man's variable characters could be extended almost without end.

One of the interests of the human geneticist is to find out which of man's variable characters have a hereditary basis. By this is meant to find out which of man's characters vary as a result of variations in hereditary factors. Characters may also vary as a result of variations in environmental factors, but a study of the rôle of these factors is primarily the concern of the human ecologist.

Having decided that a particular character has some hereditary basis the human geneticist proceeds to determine the exact manner in which that variable character is inherited—to decide whether it is inherited as a simple Mendelian dominant or recessive or in some more complex Mendelian way. Frequently this is not an easy task, not only because the mode of inheritance may be complex but also because man's own biological characteristics make it a difficult one. His generation span is long and his family size is small. Furthermore, society imposes certain restrictions upon the human geneticist. He is not permitted to order matings to test his hypotheses. However, despite these handicaps and restrictions, the human geneticist has determined the exact manner in which a fairly large number of variable human characters are inherited.

In recent years the human geneticist has developed a new interest. He has become interested in the distribution in populations throughout the world of the hereditary units or genes of the variable characters whose inheritance he has established. His goal is to know the distribution of all human genes in all populations—the distribution in all small local communities, in all cities, in all nations, in all races, in all primary human stocks and eventually in the population of the entire world.

Perhaps it is appropriate at this point to outline briefly what is meant by the distribution of human genes. To the person who is familiar with the laws of heredity this discussion will seem superfluous, but to the one who is not, it may serve a purpose. Every human individual develops from a fertilized egg or zygote. In that zygote are present pairs of hereditary units or genes for all of man's inherited variable characters. There are pairs of genes present because the sperm and the egg contribute each one set. Just how many pairs of genes exist in the hyman zygote is not known, but the number probably runs into the thousands. A knowledge of the exact number is not essential to our discussion. All that needs to be appreciated is that every inherited variable human character is represented by one or more pairs of genes. (Some characters may be affected by several pairs and one pair may affect several characters.) The members of a given gene pair may vary in differ-

ent individuals. For a given pair an individual may possess two similar genes or two different genes. For instance, if the genes of a given pair are represented by the symbols A and a, then an individual may possess two A genes (AA), two a genes (aa) or one of each kind (Aa). It will be obvious that if a population consisted of 100 individuals, 90 of whom were of the AA type and 10 were of the aa type, then the frequencies of the A and a genes in that population would be 90 per cent. and 10 per cent., respectively. Likewise, if a population consisted of 50 individuals, 2 of whom were of the Aa type and 48 were of the aa type, then the frequencies of the A and a genes in that population would be 2 per cent. and 98 per cent., respectively. In the determination of the frequencies of the genes of a variable human character it is not possible to count the genes as such, but if the mode of inheritance of the character is known, and if the frequency of the character in a population is determined, then it is possible to calculate the frequency of the gene or genes for that character in that population.

To date the distributions of only a small number of human genes have been studied and each of these in a very limited way. However, some of the studies are very interesting and informative, and it is with a few of these that I wish primarily to deal in this article. First I shall present some of the data which have been collected and then I shall attempt to relate the observed distributions to well-known evolutionary processes.

Color Vision

One variable human character whose mode of inheritance has been established and whose gene distribution has been studied to some extent is man's color vision. As every one knows, most persons can distinguish all the colors of the visible spectrum from violet to red. They are said to possess normal color vision. A few can not distinguish between the red and green colors. They are said to be red-green color-blind.

Color-blindness has probably been present in the human species from time immemorial, but its discovery dates back only to the eighteenth or possibly to the seventeenth century. At least to my knowledge no record of its occurrence appears in the literature prior to that time. In 1684 Dr. Tuberville reported to the Royal Society of London a patient who could not distinguish colors. There is some question whether this patient was red-green color-blind or had some other eye defect. A more certain case was reported in 1777 by Mr. Hudderts. In 1794 the English chemist Dalton announced his defective color vision. His announcement created so much discussion that red-green color-blindness has frequently been referred to as Daltonism. While I have no objection to a character of man being given the name of a chemist, the appellation seems inappropriate not only because it is not descriptive of the anomaly but also because Dalton was probably only partially color-blind.

That red-green color-blindness has a hereditary basis was realized soon after its discovery. Its exact mode of inheritance, however, was not established before 1910 or 1911. At that time it became appreciated that red-green color-blindness is inherited as a sex-linked recessive character. By this is meant that the gene for color-blindness (cb) is carried in the X-chromosome and that this gene does not express itself except in the *absence* of the gene for normal color vision (Cb).

As early as the middle of the nineteenth century attempts were made to estimate the frequency of red-green color-blindness in various populations throughout Europe and the United States. Most of these estimates were inaccurate, due either to smallness of

number tested or to unreliable ways of determining the character. Oddly enough, one estimate was made by a poet and found its way into poetry. In 1878 the American poet Oliver Wendell Holmes wrote inquiringly as follows:

Why should we look one common faith to find,
Where one in every score is blind?
If here on earth they know not red from green,
Will they see better in things unseen?

Holmes's estimate of one color-blind in every twenty is nearly correct. It is especially so if we have in mind a typical American population. In other populations, as I shall point out later, the frequency may be considerably different.

An interesting feature of red-green color-blindness is its greater rarity among women than among men. For a long time it was believed that this difference was due merely to a greater familiarity with colors on the part of women. Colored yarns were used for testing purposes and it was thought that some color-blind women recognized red and green colors even though they did not see them as such. We know now that this explanation is not the correct one, and that the real explanation lies in the manner in which color-blindness is inherited. According to theory, the frequency of a sex-linked recessive character, among the females of a population in which mating is at random, should be equal to the square of the frequency of the character among the males. Thus, if 10 per cent. (1/10) of the males of a population show a sex-linked recessive character, then only 1 per cent. (1/100) of the females should show it.

In Table I are given the percentage frequencies of color-blindness among the males and females of a number of populations from various regions of the world. This list does not include all the studies which have been made, but it does include most of the recent ones in which Ishihara's color charts have been used for diagnostic purposes. It would be desirable to have this list extended. Particularly welcome would be data from Africa, Italy, India, Japan, Russia and England, and also from additional racially distinct populations in the Americas.

Table I also gives the percentage frequencies of the color-blind gene (*cb*) and of the normal color vision gene (*Cb*) in the populations listed. These percentage frequencies are not given separately, but they can be read directly from the frequencies of the character among the males. The frequency of a sex-linked recessive gene, in a population mating at random, is the same as the frequency of the character among the males of that population. Thus, for instance, if 10 per cent. of the males of a population show a sex-linked recessive character, then the frequency of the sex-linked recessive gene for that character is 10 per cent. It follows, of course, that the frequency of the sex-linked dominant gene for the opposing character is 90 per cent.

Let us examine the percentage frequencies given in Table I. It will be seen that the frequency of color-blindness among the males of Norwegian and German populations is about 8 per cent. This means that there are in these populations about 8 color-blind genes (*cb*) for every 98 normal color vision genes (*Cb*). Other studies indicate that these frequencies hold for most north European countries. As shown in Table I they also hold for U. S. Caucasoids. A somewhat lower incidence is recorded for American Jews and American immigrant Spaniards when they are considered independent of other American Caucasoids. Among U. S. Negroes the color-blind gene (*cb*) is only about half as common as it is among U. S. Caucasoids; consequently, there are proportionately only about half as many color-blind Negroes in the United States as there are Whites. Among Chinese the

TABLE I

FREQUENCY OF COLOR-BLINDNESS AND OF THE COLOR-BLIND GENE (CB) IN VARIOUS POPULATIONS

Population	Investigator	Males		Females	
		Number tested	Per cent. color-blind	Number tested	Per cent. color-blind
Norwegians (Oslo)	W	9,049	*8.0	9,072	.4
Germans	P	2,000	8.0	3,000	.4
Caucasoids, U. S. (Unselected) ..	G	795	8.4	232	1.3
Caucasoids, U. S. (Unselected) ..	M	1,286	8.2	....	..
Caucasoids, U. S. (Jews)	G	200	4.0	175	0.0
Caucasoids, U. S. (Spaniards) ..	G	346	3.8	390	0.8
Mexicans (Old Mexico)	G	571	2.3	494	0.6
Mexicans (Immigrants, U. S.) ..	G	523	2.5	469	0.9
Negroes, U. S.	Cl	325	3.7	....	..
Negroes (South U. S.)	G	538	3.9	496	0.8
Negroes (North U. S.)	G	254	2.8	165	0.0
Chinese (Chengtu)	K-B	1,115	6.3	....	..
Chinese (Peiping)	CH	1,164	6.9	1,132	1.7
Indians, U. S.	Cl	624	1.9	202	0.0
Indians (various tribes)	G	562	2.5	337	0.0
Indians (Navajo)	G	535	1.1	456	0.7
Indians (mixed blood)	G	480	5.2	523	0.8

* The percentage frequency of color-blindness among males is also the percentage frequency of the color-blind gene *cb* in the population.
Ch = Chang, Cl = Clement, G = Garth, K-B = Kilborn and Beh, M = Miles, P = von Planta, and W = Waaler.

color-blind gene has a fairly high incidence. Its frequency is about midway between those of U. S. Negroids and U. S. Caucasoids. Among U. S. Indians its incidence is the lowest found in any group so far.

Probable explanations for the distributions of the color vision genes and those of other characters will be reviewed later.

Ability to Taste

Another human character whose exact mode of inheritance has been established and whose gene distributions have been studied to some extent is the inability to taste the chemical phenyl thiocarbamide. (We shall refer to this chemical as P. T. C.) About ten years ago a chemist was preparing some P. T. C. in one of America's chemical laboratories. While doing so some of the chemical escaped into the air and a co-worker complained bitterly about its taste. This complaint surprised the first chemist, because he was not aware of any taste. In fact, he could not taste the substance, even though a considerable quantity of its crystals was placed upon his tongue. To decide who was the odd or peculiar individual the two chemists called in several other men to act as jurors. To the astonishment of all present some could taste the chemical while others could not. To all those who could taste it, the taste was bitter. The rest could taste nothing.

News of this striking difference among human individuals reached human geneticists. It aroused their interest, and soon thousands of people were tested for their ability to taste P. T. C. In a short time it was discovered that about 70 per cent. of American people are P. T. C. "tasters" and 30 per cent. are "non-tasters." These studies also revealed that the inability to taste P. T. C. has a familial incidence and that it is inherited as an autosomal recessive. Matings between "non-taster" and "non-taster" give only children who are "non-tasters," whereas matings between "tasters" or between "non-taster" and "taster" may give some children who are "tasters" and some who are not.

In Table II are given the percentage frequencies of "taster" and "non-taster" groups in populations from various regions of the world. The frequencies for the "taste" gene (T) and for the "non-taste" gene (t) are also given. These gene frequencies have been calcu-

lated directly from the "non-taster" group. In a population in which mating is at random the frequency of an autosomal recessive character should represent the square of the frequency of the autosomal recessive gene. Thus, if the frequency of the autosomal recessive character is known, it is possible to calculate the frequency of the autosomal recessive gene by extracting the square root of the frequency of the recessive character. For example, if an autosomal recessive character has a frequency of 25 per cent. (1/4) in a population mating at random, then the frequency of the recessive gene in that population is 50 per cent. (1/2).

It will be seen that the "non-taste" gene (t) is about equally common in Caucasoid and Negroid populations. At least there is no striking difference between these two groups. Among Mongoloids it is somewhat rarer. Of interest is the uniformity of the t gene frequencies among all Mongoloids. Even the full-blooded American Indians have about the same "non-taste" gene frequency as do Japanese and Chinese populations.

Pitch of Voice

Here I should like to call attention to a variable human character which has not been studied extensively, but whose inheritance and whose gene distributions should prove of interest to many. Some years ago it was discovered that the pitch of the human voice is influenced by one major pair of autosomal genes. Interestingly enough, these genes express themselves differently in the two sexes. A man who is the possessor of the two similar genes ($V^{bs}V^{bs}$) sings bass, while a woman who is the possessor of the same two genes sings soprano. In the table which follows are given the voices resulting from the various gene combinations:

	$V^{bs}V^{bs}$	$V^{bs}V^{ta}$	$V^{ta}V^{ta}$
Male	Bass	Baritone	Tenor
Female	Soprano	Mezzosoprano	Alto

From the table above it will be obvious that a marriage between a basso and a soprano can give only children who sing bass or soprano; and a marriage between a tenor and an alto can give only children who sing tenor or alto. Only a baritone and a mezzosoprano can hope to produce a quartet.

Although the distributions of the bass-soprano gene (V^{bs}) and of the tenor-alto gene (V^{ta}) have not been studied extensively, there is some evidence that the former has a higher incidence in northern Europe than it does in Italy and other Mediterranean countries, and, con-

TABLE II

Frequency of the Phenyl Thiocarbamide "Taster" and "Non-taster" Groups, and of the T and t Genes in Various Populations

Population	Investigator	Number tested	Group percentages: Taster	Group percentages: Non-taster	Gene percentages: T	Gene percentages: t
Caucasoid, U. S.	S	3,643	70	30	45	55
Caucasoid, U. S.	P	439	69	31	44	56
Southern Jew (Palestine)	Y	175	72	28	47	53
Northern Jew (Palestine)	Y	245	68	32	44	56
Semenites (Palestine)	Y	59	68	32	43	57
Arabs (Syria)	H–P	400	63	37	40	60
Egyptians	H–M	208	76	24	51	49
Negroes, U. S. (Alabama)	H–C	533	77	23	51	49
Japanese	R	8,824	93	7	73	27
Chinese	C–C	167	94	6	75	25
Formosans (Aborigines)	R	1,756	95	5	77	23
Formosans (Chinese origin)	R	5,933	89	11	68	32
Indians F. B. (U. S.)	L–A	183	94	6	75	25
Indians M. B. (U. S.)	L–A	110	87	13	64	36

C–C = Chen and Chain, H–C = Howard and Campbell, H–M = Hickman and Marcos, H–P = Hudson and Peter, L–A = Levine and Anderson, P = Parr, R = Rikimaru, S = Snyder, Y = Yunovitch.

versely, that the latter has a higher incidence in southern Europe. As yet no studies of the distribution of V^{bs} and V^{ts} genes in the United States have been made.

The A–B Blood Groups

Of all human characters which have been proved to have a genetic basis, the A–B human blood groups have been studied the most, not only with respect to their importance in blood transfusions, but also with respect to the distributions of the genes responsible for them. These studies have literally run into the hundreds. Many of them have not been extensive, but when they have been carefully done, they have contributed something to our knowledge of human gene distributions.

Human bloods, as every one knows from his acquaintance with blood transfusions, fall into four major groups. The names given to these four groups are: AB, A, B and O. These names are given on the basis of (1) the presence or absence of one or both of two agglutinable substances (isoagglutinogens), A and B, which are found in the red blood cells, and (2) the presence or absence of one or both of two agglutinating substances (isoagglutinins), a and b, which are found in the blood serum. The relationships of these substances to the groups are shown in the table which follows:

Blood group	Isoagglutinogen		Isoagglutinin	
AB	A and B		None	
A	A	......	...	b
B	......	B	a	...
O	None		a and b	

It will be noticed that if an isoagglutinogen is present in the red blood cells of an individual, then the corresponding isoagglutinin is absent in the serum of that individual. In blood transfusions the important consideration is not to introduce isoagglutinogens in the blood of the donor which will be agglutinated by isoagglutinins in the blood of the recipient or host.

As was implied in an earlier statement, the A–B blood groups have been shown to have a hereditary basis. Furthermore, they have been shown to be inherited in accordance with a theory of triple allelomorphs. By this is meant that a given locus on a chromosome is represented by three different genes which can combine in all different ways in groups of two. The three genes responsible for the four human blood groups have been called the I^A, the I^B and

TABLE III

Frequency of Blood Groups AB, A, B and O and of the Blood Group Genes, I^A, I^B and i in Various Populations

Population	Investigator	Number investigated	Group percentages				Gene percentages		
			AB	A	B	O	I^A	I^B	i
Caucasoid, U. S.	Sn	20,000	4	41	10	45	26	7	67
Caucasoid, U. S.	Sa	3,000	4	42	9	45	27	7	66
Germans (Heidelberg)	D	500	5	43	12	40	28	8	64
Germans in Hungary	V–W	476	3	43	13	41	27	8	65
Hungarians	V–W	1,500	12	38	19	31	29	17	54
Gypsies (Hungary)	V–W	385	6	21	39	34	14	26	60
Hindus (N. India)	H–H	1,000	9	19	41	31	15	29	56
Negroes (West Africa) ...	L–H	325	3	22	23	52	13	14	72
Negroes (U. S.)	Sn	500	5	28	20	47	18	13	69
Japanese (Ou district) ...	F	24,672	9	37	23	31	26	18	56
Chinese (Peiping)	L–W	1,000	10	25	35	30	20	26	54
Chinese (Hunan)	L–C	1,500	10	38	21	31	28	17	55
Indians F. B. (Peru)	L	200	00	00	00	100	00	00	100
Indians F. B. (U. S.)	Sn	453	00	8	1	91	4	1	95
Indians F. B. (Blackfeet) ..	M–L	394	1	77	00	22	54	1	45
Indians M. B. (Blackfeet) ..	M	235	2	51	2	45	31	2	67

D = von Dungern, F = Furuhata, H–H = L. and H. Hirsfeld, L = Larreta, L–C = Li Chi Pan, L–H = Lewis and Henderson, L–W = Liu-Wang, M = Matson, M–L = Matson, Levine and Schrader, Sa = Sanford, Sn = Snyder, V–W = Verzar and Weszecsky.

TABLE IV

TABLE SHOWING THE FREQUENCY OF THE BLOOD GROUPS MM, MN AND NN AND OF THE BLOOD GROUP GENES A^m AND A^n IN VARIOUS POPULATIONS THROUGHOUT THE WORLD

Population	Investigator	Number investigated	Group percentages			Gene percentages	
			MM	MN	NN	A^m	A^n
Caucasoids, U. S.	L–L	532	26	54	20	53	47
English	T–P	422	29	47	24	52	48
Germans	Bk	2,000	29	49	22	54	46
Russians (Leningrad)	Bv	763	32	47	21	55	45
Hindus	C	300	43	47	10	66	34
Negroes, U. S.	L–L	181	28	47	25	51	49
Chinese	R	1,029	33	49	18	58	42
Japanese	H	1,000	29	51	20	55	45
Ainu	K	504	18	50	32	43	57
Eskimos (East Greenland)	F–H	569	83	16	1	91	9
Indians, U. S.	L–L	205	60	35	5	78	22
Indians, F. B. (Pueblo)	A–L	140	59	33	8	76	24
Indians, F. B. (Blackfeet)	M–S	95	55	40	5	75	25
Indians, M. B. (Blackfeet)	M–S	272	18	56	26	46	54

A–L = Allen-Larson, Bk = Blaurock, Bv = Blinov, C = Combined results, F–H = Fabricius-Hanson, H = Haschimoto, K = Kubo, L–L = Landsteiner and Levine, M–S = Matson, Levine and Schrader, R = Ride, T–P = Taylor and Prior.

the i genes. The following table shows the gene combination (or combinations) responsible for each group:

Blood group	Gene combination
AB	I^AI^B
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
O	ii

As indicated in an earlier paragraph, hundreds of studies on the frequency of the human blood groups have been made. It would be neither possible nor appropriate to introduce all of them here. A few have been chosen for representative purposes. These are given in Table III. In Table III are also given the frequencies of the three blood group genes. These gene frequencies have been calculated from the observed group frequencies. According to theory an estimate of the frequency of the I^A gene may be obtained by extracting the square root of the sum of the frequencies of groups B and O, and subtracting this result from 1. Likewise, an estimate of the frequency of the I^B gene may be obtained by extracting the square root of the sum of the frequencies of groups A and O and subtracting this result from 1. And finally, an estimate of the frequency of the i gene may be obtained by subtracting from 1 the sum of the calculated frequencies of the I^A and the I^B genes.

Among northern Europeans and U. S. Caucasoids the i gene has a frequency of about 66 per cent. As a result nearly half of the people of these populations belong to group O. The I^B gene on the other hand is comparatively rare in these populations and consequently the B group and also the AB group are rare. In southern and southeastern Europe the I^B gene is more common and the I^A gene is less common than the respective genes are in northern Europe. Among Negroids the i gene is apparently slightly more common than it is among Caucasoids. The I^A gene frequency on the other hand is relatively low. Among Mongoloids the A–B blood group genes are extremely variable in frequency. Among Chinese and Japanese the I^A and I^B gene frequencies are relatively high. The I^B gene is particularly common in comparison with its frequency among Caucasoids of northern Europe. However, it is not more common among these populations than it is among the Caucasoids of India. Among some Indian tribes of the United States and of Peru the I^A and I^B genes are nearly absent. In fact, it is believed by some that they are completely absent among full-blooded Indians of these tribes. Among the Blackfeet Indians of the U. S. Northwest, on the other hand, the I^A gene has

the highest frequency that has been discovered for any human population, be it Mongoloid, Negroid or Caucasoid.

The M–N Blood Groups

In addition to the four A–B blood groups, and entirely independent of them, human bloods fall into three other classes. These are the MM, the MN and the NN groups. The M–N groups differ from the A–B series in that their agglutinating substances (agglutinins) are never normally present in human blood. They must be induced in the tissues of other animals.

The M–N blood groups are also inherited, but in a manner somewhat different from the A–B series. The three M–N groups are dependent upon the presence or absence of one or the other of a pair of genes called the A^m and the A^n genes. The table which follows shows the gene combinations responsible for the three groups:

Blood group	Gene combination
MM	A^mA^m
MN	A^mA^n
NN	A^nA^n

Neither the A^m nor the A^n gene is dominant over the other. Matings between individuals of group MM and of group NN produce children all of whom belong to group MN; and matings within the MN group produce children ¼ of whom are expected to belong to group MM, ½ to group MN, and ¼ to group NN.

In Table IV are given the M–N group frequencies and the A^m and A^n gene frequencies for a number of populations. The A^m and A^n gene frequencies have been calculated directly from the group frequencies. Since neither the A^m nor the A^n gene is dominant over the other it is possible to obtain the gene frequency of a population from the group frequencies. In any population the A^m gene frequency equals the MM group frequency plus ½ the MN group frequency; and the A^n gene frequency equals the NN group frequency plus ½ the MN group frequency.

It will be evident from a study of Table IV that the A^m and the A^n gene frequencies are nearly the same for a majority of all Caucasoid, Negroid and Mongoloid populations. The peoples showing the greatest deviations from the average are the Ainu and the Eskimos of Greenland. The Ainu have a relatively low A^m and a relatively high A^n frequency, while the Greenland Eskimos have a very high A^m and a very low A^n frequency. The American Indians resemble the Eskimos of Greenland somewhat in having a relatively high A^m and a relatively low A^n frequency. However, the deviation from the average is not so great for the Indians as it is for the Eskimos. Since the Blackfeet Indians have been shown to differ so strikingly from other Indian tribes in their I^A and i gene frequencies, it is an interesting fact that they are very similar to other Indian tribes in their A^m and A^n gene frequencies.

Shape of Red Blood Cells

The distributions of the genes for several other inherited human characters could be reviewed, but only those of one more will be mentioned, namely, those for the shape of human red blood cells. The red blood cells of certain human individuals become crescentic or sickle-shaped when their blood is exposed outside of the body to certain special conditions. Some individuals whose blood shows these peculiar cells are anemic; consequently, the character was originally called sickle-cell anemia. Anemia, however, does not always accompany the character; therefore, it seems more appropriate to refer to the character as sickle-shaped erythrocytes. Sickle-shaped erythrocytes is of interest to human geneticists because it has been proved to have a hereditary basis, and

also because it has been found only among Negroes.

According to the few genetic studies which have been made, sickle-shaped erythrocytes is inherited as an autosomal dominant. The dominant gene for sickle-shaped erythrocytes has been called the *Si* gene, and the recessive gene for the opposing normal red blood cells the *si* gene. Only a few estimates of the frequency of sickle-shaped erythrocytes have been attempted, but all these indicate that about 7 per cent. of all American Negroes possess this character. If this estimate is correct, then the *Si* and the *si* genes have frequencies in the American Negro population of about 4 per cent. and 96 per cent., respectively. As far as I am aware, no studies have been made of the incidence of sickle-shaped erythrocytes in Africa. Such studies woud be interesting and welcome.

Probable Explanations

Having reviewed in a somewhat summary fashion the observed distributions of the genes of a few variable human characters, I shall attempt to account briefly for these distributions in terms of well-known evolutionary factors. No final answers can be given, but a few probable explanations can be presented.

At the basis of all genetic variability and consequently of all gene distributions is the factor of genetic change. Without this factor operating there would be no genes to be distributed. Without it there would be no human species, not even lower forms as we know them—probably no life at all.

Genetic changes are fundamentally of two kinds: Those which represent visible changes in the larger units of the cell, called the chromosomes, and those which represent changes in the ultimate hereditary units or genes. The former are known as chromosome mutations and the latter as gene mutations. We shall be concerned primarily with the latter, not because the former have played no rôle in the evolution of man (they probably have played an exceedingly important rôle), but because a discussion of them appears to lie outside the scope of the present article. We shall be concerned only with the distribution of human genes and not with the detailed story of human evolution.

New gene mutations are fairly common. At least they are so among lower forms. Any one working with the small fruit-fly (*Drosophila*) for any length of time will, if he is an acute observer, sooner or later discover a new mutation. Hundreds of them have been reported and established for this form. Even within the human species several new mutations have been observed. A few years ago a type of permanent hair cut appeared as a new character in a Norwegian family. The hair grows out a few inches and then breaks off. Because the hair is also extremely curly the new mutation has been called "Woolly Hair." This character is inherited as a Mendelian dominant. A number of other specific illustrations of human mutations could be cited, but suffice it to say that mutations do occur in man and not infrequently so. One estimate places the rate of mutation of a particular human gene at one mutation for every 50,000 individuals per generation.

In accounting for the human gene distributions which have been observed I shall ask three questions and then attempt to answer each of them. The three questions are: (1) How can the differferences, in the extent to which various human gene mutations are distributed, be explained? (2) How can the high or low frequencies of the observed human gene mutations be accounted for? (3) How can the differences in the frequencies of the same gene in different populations be explained?

The time at which a given gene mutation occurs in the evolutionary history of

a species is an important factor in its subsequent distribution. If it occurs before a species has become separated into numeorus distinct populations it has a better chance of becoming universally distributed than if it occurs later, for it can be carried directly by all populations as they radiate out from the ancestral stock. Regarding the human gene mutations whose distributions have been reviewed, there is reason to believe that most of them appeared early in the evolution of man. The only exception is probably the *Si* gene for sickle-shaped erythrocytes. Since this gene is found only among Negroes, it seems probable that it represents a mutation of relatively recent origin.

The best available evidence that some of the observed human gene mutations are of ancient origin is given by the A–B blood group genes. According to several investigators the Anthropoid apes possess A and B isoagglutinogens which are serologically identical with those found in man. Even all the four blood groups found in man have been discovered for the Anthropoid apes. This fact can only mean that these first cousins of man possess blood group genes identical with or at least very similar to those present in man; and it suggests strongly that the mutation or mutations which are responsible for the blood group genes in both lines occurred early in the common ancestral stock. There is even a suggestion that these mutations may have occurred earlier in the evolutionary history of mammals, because there is some evidence that A–B blood groups exist below the primate branch.

A gene mutation need not necessarily occur in the ancestral stock of a species in order for it to become universally distributed. It is possible for it to be distributed as a result of migrations and intermarriages. While this is a possible explanation for the common occurrence of a number of human genes, it is not a very probable one for the universal distribution of most of the mutations which have been reviewed. Intermarriages between different primary human stocks have not taken place to this extent in the remote or even in the recent past. However, it seems certain that this factor will play a greater and greater rôle as time passes. With modern methods of communication and travel this can not be prevented. For instance, it seems certain that the sickle-shaped erythrocyte gene (*Si*) will eventually filter into the Caucasoid and Mongoloid stocks.

Another way in which a given kind of gene mutation may become universally distributed, without appearing as a result of a mutation in the common ancestral stock or as a result of intermarriages between populations, is for the same mutation to appear in all populations. There is ample evidence from studies with lower forms that this may occur. Duplicate gene mutations have even been reported for man. For instance, the gene for normal blood clotting (*H*) has been reported to mutate in different populations to the gene for haemophilia (*h*). Some investigators are of the opinion that the occurrence of duplicate gene mutation is the most probable explanation for the universal distribution of the blood group genes among human populations and also for their common occurrence among Anthropoid apes and man. While I admit this possibility, I am inclined to believe that the ancestral mutation hypothesis is the more probable. I recognize, however, that some of the blood group genes which are found in both Anthropoid ape and human populations may represent recent mutations.

The second question which is to be answered concerns the high and low frequencies of the different observed human mutations. How are the high frequencies of many of the observed gene mutations to be accounted for? Many people

are of the opinion that if a new character appears in a population and that if it has a hereditary basis, then it will automatically persist and increase in frequency. This is an unwarranted assumption. Heredity in and of itself does not insure persistence of a new mutation nor does it by itself bring about an increase in frequency of that mutation. Such increases, if they do occur, are due to other factors.

Among the more important factors which may lead to a persistence and an increase in the frequency of a new mutation is Natural Selection. Gene mutations are random or nearly random in nature. They apparently bear no specific relationship with the environment in which they occur. Since they are random or at least nearly so it is not surprising to find that most of them have a negative survival value for the individual or the species in which they occur. By negative survival value is meant that they tend to produce individuals who will not survive as readily or leave as many offspring as the individuals who show the character of the original gene. Obviously such mutations which have a negative survival value will tend to be eliminated from a population.

A fairly large number of the mutations which occur are said to be indifferent. By this is meant that they are neither selected for nor against. Such mutations should remain constant in frequency so far as natural selection is concerned but may disappear or increase in frequency for reasons which will be presented later. A few mutations have a positive survival value. By this is meant that the individuals who show the mutations will tend to survive to a greater extent than the individuals who show the character of the original gene. Naturally such gene mutations will tend to increase in frequency in a population. It does not follow, however, that all of them will survive.

Of the human gene mutations whose distributions have been reviewed, only a few seem to have a higher or lower survival value than the genes from which they mutated. These are the color-blind gene (*cb*) and the sickle-shaped erythrocyte gene (*Si*). It seems probable that in a primitive society the color-blind gene (*cb*) may have a slightly lower survival value than the gene for normal color vision (*Cb*). This may account for its relatively low incidence among full-blooded Indians and among Negroes. Their civilizations in which selection might have operated against the *cb* gene are more recent than those of the other peoples whose gene frequencies have been studied. It might seem to some persons that in a modern society which employs red and green "stop and go" signals, selection would also operate against the *cb* gene. The opposite is probably true. Color-blind men are not allowed to drive locomotives and other vehicles of traffic. Furthermore, it has been a custom in the past to exempt color-blind men from active participation in wars and other hazardous activities. Such exemption would naturally tend to increase the frequency of the *cb* gene. Recent discoveries may alter this trend. It has been reported recently that color-blind men can spot certain bombing objectives from the air more readily than men with normal color vision. If this should turn out to be true, then there may be a special demand for color-blind men in a very hazardous occupation and the frequency of the *cb* gene should then decrease.

The *Si* gene appears to have a negative survival value because anemia is frequently associated with the sickle-shaped erythrocyte condition. I must admit, however, that I do not know to what extent this form of anemia leads to death or to decreased reproductive capacity, but it seems probable that it does to some extent.

There is one more of the introduced variable human characters whose genes may have a differential survival value. This is the pitch of the human voice. It seems probable that either the bass-soprano gene (V^{bs}) or the tenor-alto gene (V^{ta}) may have a lower survival value than the other, but in view of a possible storm of protest, I shall not voice an opinion against the one or the other.

A number of attempts have been made to establish a differential survival value for the blood group genes. But to date no positive or negative survival value has been found for any one of them. Likewise no differential survival value has been discovered for the ability or inability to taste the chemical phenyl thiocarbamide.

If selection has not been responsible for the high incidence of most of the gene mutations whose distributions have been reviewed, what factor has? Perhaps the most important one has been recurrent mutations. We have already pointed out that the same mutation may occur in different populations. Naturally if this is true it may also recur in a given population. If a certain mutation recurs very often in a given population it will increase in frequency in that population in the absence of selection. It may even increase in the presence of a low selection pressure. As far as I am aware there is not much direct evidence that the blood group genes or the taste genes are mutating, but this is not surprising in view of the fact that these characters are not detected unless special tests are used. Other mutations like haemophilia are known to recur fairly frequently. In fact, it was the gene for normal clotting (H) which was estimated to mutate to the haemophilia gene (h) as often as once in every 50,000 individuals per generation.

Although recurrent mutations as a factor have been given credit for many of the observed high frequencies of human gene mutations, it must be pointed out that a gene may have an effect which has a positive survival value even though the character associated with it does not. Many genes have multiple effects and their most important effects are frequently not discovered. Thus natural selection may frequently be playing an unsuspected rôle. Furthermore, it should be emphasized that the positive survival value of a gene need not be very great for a marked increase in gene frequency if a long time is allowed for selection to operate.

The third question which is to be answered concerns differences in the frequencies of a given gene in different populations. For instance, what explanation can be offered for the complete absence of the I^A gene among Indians of Peru and the high incidence of the same gene among the Blackfeet Indians of the U. S. Northwest? Perhaps the most probable explanation for a number of these differences is the matter of chance. If an original large population has a fairly high incidence of a given mutation and if from that population a number of small populations migrate to distant regions, then there is the possibility, merely as a result of chance, that one group will carry away a high frequency of the mutation and another a low one. It seems probable that this is at least a partial explanation for the blood group frequency differences among Indians. It probably also is the best explanation for the high A^m and the low A^n gene frequencies of the Eskimos of eastern Greenland.

If the group which migrates from the original population is large or representative of the population as a whole, then the gene frequencies in the new population should resemble closely those of the old or original one. Examples of this are common. The similarity of the blood group gene frequencies of the U. S. Negroes and those of West Africa is a case

in point. Two other interesting illustrations were brought to light some years ago. In 1922 two investigators tested the bloods of a colony of Germans who were living in Hungary but who were not intermarrying to any extent with the surrounding Hungarians. When their blood group frequencies were calculated they were found to resemble more closely the blood group frequencies of the Germans of Heidelberg, from where their ancestors had migrated 200 years earlier, than the frequencies of the surrounding Hungarians. The same two investigators tested the bloods of a colony of gypsies, also living in Hungary without intermarrying with the Hungarians. When their blood group frequencies were calculated they were found to resemble more closely those of the Hindus of North India than those of the Hungarians. The interesting part of this story is that when the history of these gypsies was checked it was found that a philologist had decided, on the basis of their language, that the ancestors of this particular gypsy colony had migrated from North India 500 or more years earlier.

Another possible explanation for gene frequency differences in different populations is for the same gene to have different mutation rates in different populations. Such mutation rate differences have been reported for genes among lower forms, but there is no direct evidence of such mutation rate differences in man. It is true that one geneticist has used this explanation to account for the high I^A gene frequency among the Blackfeet Indians and the low frequency of the same gene among other U. S. Indian tribes. While I must admit this explanation is a possible one, it does not appear to me to be the most probable one.

Of course, if a gene has a positive or a negative survival value and if two populations exist under different environmental conditions, then selection alone may be responsible for the frequency differences. As was pointed out in an earlier paragraph, this seems a probable explanation for some of the observed frequency differences of the color-blind gene.

Many more factors and combinations of factors could be brought forth as possible and even as probable explanations for some of the observed gene distributions, but with only a limited amount of data collected such detailed discussion seems too speculative at the present time.

The Value of Human Gene Distribution Studies

Undoubtedly the greatest value of human distribution studies will be to a clarification of human racial interrelationships and to an understanding of human evolution in general. However, human distribution studies may also have some practical value. It would seem that they may be of some value in the formulation of medical and other social programs. There appears to be some value in knowing the percentage of children who will be born each year with haemophilia, with sickle-shaped erythrocytes, with color-blindness or with any other of the definitely inherited human anomalies. All in all, the study of human gene distributions promises to be one of the most fruitful avenues of research which has been opened up in the field of human biology within recent years. It is a tremendous project which requires and deserves the joint cooperation of the human geneticist, the physician, the anthropologist, the human ecologist and any other person who is interested in the story and the welfare of the most interesting of all animals, MAN.

THE NORMAL BURNING OF GASEOUS EXPLOSIVE MIXTURES

I. Explosions at Constant Pressure and at Constant Volume

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INTRODUCTION

IN a recent reference book called "Combustion Flames and Explosions of Gases" Lewis and von Elbe[1] make the following logical subdivisions in the field of combustion research: (1) the kinetics of reactions in the gas phase, usually involving studies of reactions which take place simultaneously throughout all the gas mixture, (2) the passage of flame progressively through the gas mixture, with consequent existence of a surface or region of demarcation between the burned and unburned gases, and (3) the state of the burned gas.

Since the scope of the present report must be limited, and since the experience of the author has been in the field involving progressive flames, the discussion will be confined, for the most part, to the second of the three phases mentioned above. Further limitation is made by including only explosions involving normal burning, that is, burning in the absence of detonation, except in the case of combustion in the engine cylinder where detonation or knock has been the principal subject of investigation.

It may not be amiss to begin with a brief historical background, recalling the principal elements of the foundation upon which recent studies of the combustion process are based. The following section is a digest of a detailed presentation made by Bone and Townend.[2]

[1] B. Lewis and G. von Elbe, "Combustion Flames and Explosions of Gases," London: Cambridge University Press, 1938.

[2] W. A. Bone and D. T. A. Townend, "Flame and Combustion in Gases," London: Longmans, Green and Company, 1927.

HISTORICAL

Judging by modern standards, it appears that the earliest truly scientific studies of flame and combustion were made by Robert Boyle and his pupils about 1630, more than one hundred years before the discovery of oxygen. In 1665 Robert Hooke, one of Boyle's pupils, published a treatise showing that heating certain combustible materials either in air or mixed with niter produced a "shiny transient body which we call flame, which is nothing but a mixture of air and volatile constituents of combustible bodies acting upon each other as they ascend." Nine years later John Mayow, also a pupil of Boyle, advanced the theory that two things are necessary for combustion, namely flammable particles and aerial particles, which are so hostile that they enter into sharp conflict when suitably brought together, whereby they are thrown into violent motions resulting in the appearance of fire.

In retrospect it would seem that, had it not been for his death at the age of thirty-six, such a brilliant experimenter as Mayow would surely have come to recognize that the aerial particles which he postulated were a part, but not all, of the air, and that combustion was not an interplay but the actual combining of the two kinds of particles. Unfortunately no one appeared, either among his contemporaries or immediate successors, to reflect his teachings, and another view of combustion known as the Phlogiston Theory became prominent until the middle of the eighteenth century.

This alchemistic notion that combustible substances contained the ponderable principle phlogiston, which, on rapid escape, caused the appearance of fire, was doomed by the discovery of various pure gases. In 1775 Black discovered CO_2 and showed that it was present in small amounts in the air. Between 1767 and 1777 Priestly and Scheele discovered several new gases, each having properties different from air, and laid the foundation for modern gas chemistry, incidentally providing Lavoisier with material to disprove the Phlogiston Theory, and enabling him to substitute therefor the oxygen theory of combustion which has since been amply verified.

In the first decade of the nineteenth century John Dalton made two contributions of importance in the field of combustion, namely the atomic theory and the discovery that explosions of certain mixtures of methane and ethylene with oxygen produced carbon monoxide and hydrogen rather than carbon dioxide and water. This latter observation seems to have been overlooked for the ensuing eighty years during which theories involving the preferential oxidation of hydrogen in hydrocarbons flourished.

In the second decade of the nineteenth century Sir Humphry Davy found that there are certain fairly definite limits of explosibility for each flammable gas when mixed with air or oxygen, and that the stimulus required to produce ignition varied in intensity from mixture to mixture. A great many similar determinations of the limits of flammabilty and of so-called ignition temperatures have since been made.

Since Davy had deduced that a certain temperature was required to ignite a specific explosive mixture, it was logical to assume that a continuous transfer of heat to the unburned gas ahead of the flame was essential to its propagation. Thus, when confronted with the problem of accidental explosions in mines, he saw the desirability of interposing between the most probable source of ignition and the bulk of the gas in the mine some material which would effectively reduce the quantity of heat flowing from the burned to the unburned gas, and thus extinglish the flame near the source of ignition. He found experimentally that small tubes, particularly if they were good thermal conductors, did actually accomplish this purpose in mixtures obtained from mines. From small tubes to wire gauze was a logical step, and the Davy Safety Lamp resulted. This invention, which in his own words consisted "in covering or surrounding the flame of a lamp or candle by a wire sieve," is one of the first important practical results of combustion research.

Davy's subsequent work included the first recorded studies of the temperatures of flames and of catalytic combustion, both of which are still very live subjects of investigation.

The period from 1836 to 1880 has been frequently called the Bunsen era because it was so completely dominated by the influence of this great chemist and his pupils.

Among the more important contributions of Bunsen are the perfection of methods for quantitative analysis of gases, the application of such methods to mixtures of gases in the blast furnace, which resulted in one of the greatest advances in scientific metallurgy, and the development of the gas burner which still bears his name. Some of his other reports contained the first recorded measurements of flame speeds and of maximum pressures developed during explosions in closed containers, with the flame temperatures calculated therefrom. All of these measurements have been repeated at subsequent intervals as improved methods were devised and as new sources of error were revealed.

As is always the case during a period

of rapid advance, there appeared during the Bunsen era a number of theories which later had to be discarded. Most conspicuous were those which postulated the preferential combustion of hydrogen and which led to the conclusion that the law of mass action did not apply to gaseous explosions. Many investigators were misled because they were not aware of the possible effects of water vapor and of catalytic reactions, of which the latter may be a function of the particular apparatus. Unfortunately, these same pitfalls are not always avoided even to-day.

However the studies of explosions themselves, together with important contributions in related fields, such as Deville's investigations of thermal dissociation and accurate determinations of heats of combustion by Berthelot, Julius Thomsen and others make the Bunsen era stand out as the period during which was laid the real foundation for modern theories and endeavors in the field of combustion.

Definition and Discussion of Terms

Before proceeding further it may be well to pause for a brief discussion and, where possible, a definition of some of the terms which will be used most frequently in what is to follow. A number of these terms may be defined specifically, while many others do not seem to have universally accepted meanings. So far as is known the following definitions are comparatively free from serious objection.

1. *Flame* is gas rendered luminous by combustion or heating.

2. The *flame front* is the boundary surface between the luminous region and the dark region of unburned gas.

3. The *reaction zone* is the region of inhomogeneity in which homogeneous unburned charge is transformed into combustion products in chemical equilibrium.

4. The *spatial velocity* of the flame is the velocity with which the flame front moves in a direction normal to its surface, relative to a fixed point in the explosion vessel.

5. The *transformation velocity* is the velocity at which the flame front advances into the unburned charge in a direction normal to its surface, that is, the linear velocity with which the unburned charge is transformed chemically.

6. The *gas velocity* is the velocity with which the flame front is transported bodily in a direction normal to its surface by mass motion of the gases into which it is advancing.

7. The *expansion ratio* is the ratio of the volume of the same mass of gas before and after explosion at constant pressure.

Numerous other terms such as the limits of flammability, flame temperature and ignition temperature, the latter often further described by prefixing the words self, auto or spontaneous, are frequently used in connection with certain burning characteristics. Most of these characteristics have real practical importance, and specific definition of the terms used to describe them would be of great value. Unfortunately this has not been possible because the numerical values which have been determined are not as yet entirely independent of the apparatus in which the measurements were made, and arbitrary experimental methods have not been generally adopted.

The Modern Period

In a review of that phase of combustion research which was selected for this report it is convenient to consider the advances of the last sixty years without further regard for chronology. Instead, some additional subdivisions of the field will be made and each will be treated separately. As a first step, a distinction may be drawn between the cases in which the flame is stationary and those in which it is in motion, as is usual during explosions.

Stationary Flames

The two general classes of stationary flames are the diffusion flame, in which the mixing of the fuel and oxygen takes place in the flame itself, and the Bunsen-

type flame, in which the mixing has been accomplished before the mixture enters the flame.

Diffusion flames. Common examples of this type are flames from a burning candle, oil lamp, wood or coal. As the name implies, the characteristics of the diffusion flame are largely dependent upon the rate at which the mixing of fuel and air is accomplished in the neighborhood of the flame. The inter-diffusion of the vaporized combustible and the oxygen to form an explosive mixture is so much slower than the rate of the reaction that the latter is of only secondary importance. Therefore diffusion flames, despite their wide variety of practical applications, are not promising subjects for the study of the combustion process.

Burke and Schumann[3] evolved equations which are in fair agreement with the observed facts for diffusion flames obtained by passing gaseous fuel and air separately, and at the same linear velocity, through coaxial tubes. By these equations the effects of such factors as gas velocity, nature of the fuel and mixture ratio, upon the size of the flame, may be calculated. However, they involve coefficients of diffusion under the somewhat uncertain conditions prevailing close to the flame.

Bunsen-type flames. In the Bunsen burner, in most domestic gas appliances, and in various welding torches the fuel and air are proportioned and mixed before reaching the opening or port of the burner. Such devices are designed to burn the unconfined mixture with a flame which has more or less stability in the surrounding atmosphere. Stability is achieved by adequate control of the proportion of fuel to oxygen and of the rate at which the mixture issues from the burner port.

The velocity of flow through the port (S_m) must exceed the transformation velocity (S_t) to prevent the travel of the flame back through the port and into the mixing chamber, an occurrence commonly known as flash back. The mixture velocity may be several times the flame velocity, but above a certain ratio the flame is blown off the port. Thus the characteristics of the Bunsen flame of any mixture are largely dependent upon the rate at which it is transformed by flame, and studies of such flames may yield values of transformation velocity.

Some of the necessary concepts may be introduced by considering a hypothetical case in which it is assumed that a homogeneous explosive mixture flows without turbulence through a burner tube whose walls offer no resistance to gas flow and neither absorb nor conduct heat.

If, in such an ideal burner, the mixture velocity S_m is sufficiently greater than the transformation velocity S_t, a flame of the familiar Bunsen type with its inner cone and outer mantle may be established above the burner port, as shown diagrammatically in Fig. 1 (a). Upon decreasing the mixture velocity the height of both cone and mantle would also decrease until finally the cone approached a plane surface, which would then move down the tube as such. For a single value of S_m the flat flame could be held stationary, with a small mantle persisting at the burner port, as illustrated in Fig. 1 (b). At such a steady state the mixture velocity S_m would be identical with the gas velocity, S_u, as defined, and these velocities would be equal in magnitude but opposite in direction to the transformation velocity S_t.

Thus, in the hypothetical case, only the measurement of the linear rate of flow of the unburned mixture through the frictionless tube is needed to establish the value of transformation velocity. However, in an actual tube the gas velocity is not uniform, but varies from

[3] S. P. Burke and T. E. W. Schumann, *Indust. and Engineering Chem.*, 20: 998–1004, 1928.

practically zero at the walls to a maximum at the center, so that a plane flame can not be obtained by reducing the rate of flow. Further irregularities in the shape and position of the inner part of the flame also arise from heating the walls. Both of these difficulties can be overcome to a considerable extent if the inner cone is allowed to rest on the port of a burner, through the tube of which the gas flow is laminar, provided that proper account is taken of the shape of the actual cone.

Bunsen[4] made the first recorded measurements of the speed of flame by gradually decreasing the measured velocity of an explosive mixture through an orifice to such a value that the flame just flashed back. Modifications of this method have been used by many investigators ever since.

The flash-back method of Bunsen was not accurate because of the variation in gas velocity over the area of the port. Later Gouy[5] attempted to determine the product of the gas velocity and the sine of the angle between the side and axis of the cone, but found that the actual cone of flame departed so much from a geometric cone that there was no single, definite angle to measure. It was a logical step to consider that the speed of flame could be found by dividing the volume rate of flow through the port by the area of the cone of flame. Subsequent measurements showed that results obtained by this method involved uncertainties which could be largely eliminated by taking proper account of the velocity distribution over the area of the port.

Stevens[6] calculated transformation velocities from measured values of gas velocity and photographs of the flame cone, upon each of which he constructed a geometric cone having the diameter of the burner port as a base and having sides parallel to the flame surface at that point where the velocity of the gas mixture was equal to the mean velocity over the area of the port. His results with this procedure were in substantial agreement with those obtained by an independent method.

Smith and Pickering[7] modified Steven's treatment of the flame photographs by measuring directly the angle between the surface and the axis of the cone of flame at the points of average velocity; that is, at 0.7 the distance from the axis of the port. In a later report, Smith[8] makes the following statements concerning the determination of transformation velocities by the burner method:

1. The numerical result is independent of the velocity of flow of the mixture, so long as the flow is laminar.
2. The result depends upon the size of the port, especially if the area of the flame is used in the computations.
3. Results based on appropriate measurements of angle appear to be a more reliable index of flame speed than those based on area.
4. Maximum speed mixtures give minimum errors and are least objectionable for comparisons between fuel gases.
5. Although burner methods of measuring flame speed are relatively simple and the results directly applicable to a multitude of burner problems, the field of usefulness of the method appears at present to be considerably restricted.

Lewis and von Elbe,[9] in summarizing the possibilities and limitations of the burner method for determining transformation velocity, express their impression that not all of these have been thoroughly explored as yet. In addition to values of transformation velocity, Bunsen-type flames have been used in obtaining information concerning both the

[4] W. A. Bone and D. T. A. Townend, *op. cit.*, p. 39.

[5] M. Gouy, *Annales de Chemie et de Physique*, 18: 27, 1879.

[6] F. W. Stevens, *Technical Report No. 305*, Nat. Advisory Committee for Aeronautics, 1929.

[7] F. A. Smith and S. F. Pickering, *Jour. of Research of Nat. Bureau of Standards*, 17: 7–43, 1936.

[8] F. A. Smith, *Chem. Reviews*, 21: 389–412, 1937.

[9] B. Lewis and G. von Elbe, *op. cit.*, p. 205.

composition of the interconal gases and the temperatures which are attained upon burning various combustible mixtures.

The methods of spectroscopy have been successfully applied in the measurements of the temperatures attained in both Bunsen-type[10] and explosion flames.[11] Light from an electrically heated filament or strip is passed through the flame, colored by a trace of a salt of an alkali metal, usually sodium, and the combined radiation from lamp and flame is observed with a spectroscope. At filament temperatures below that of the flame the sodium spectrum shows the bright lines of emission. Upon increasing the filament temperature beyond that of the flame, the sodium lines become dark lines of absorption. The temperature of the filament at which the change from emission to absorption takes place is the temperature of the flame gas through which the external light is passed. It is thus logical to call this method of measuring the temperature of the inflamed gases the spectral line reversal method.

By its use much information has been obtained on the temperature gradients existing throughout the volumes of various flames, and more on the highest temperatures which are produced with different fuels, together with the effects of mixture ratio and rate of heat production upon these maximum temperatures.

Explosion Flames

For the purposes of this discussion, explosion flames, as distinguished from stationary flames, include all those which spread throughout the available explosive mixture from a source of ignition. With the exception of a few cases in which it is only necessary to decide whether or not there has been an explosion, the great majority of investigations involving explosion flames have required means for measuring the time rate of displacement of the flame from the point of ignition.

The most widely used, as well as the most useful method for determining spatial velocity is by direct photography on a film moving at a known speed. Such a picture not only serves as an accurate time-displacement record of the flame front, but also provides for a visual study of the whole flame movement. This method is generally used except in cases where insufficient light is emitted during the burning and where the introduction of a window through which the flame may be photographed is not practicable.

For flames of relatively low actinic light, the shadow and schlieren methods of photography[12] are available. Both of these utilize the effect of the sharp difference in optical properties existing at the flame front upon light from an external source. The schlieren method has the additional advantage that it indicates the progress of the pressure waves through both the unburned and burned gases.

If it is not feasible to use a transparent window in an explosion chamber, ionization gaps which break down[13,14,15] or small wires which fuse[16] when reached by the flame may be employed. These methods are not appropriate when the flame front suffers irregular changes in velocity between the gaps or wires, but have been used in engine cylinders and in measuring the very high speeds of detonation in long, metal tubes.

In all explosions originating at a point

[10] *Ibid.*, chap 19.

[11] G. M. Basweiler and L. Withrow, *Soc. Automotive Engineers Jour.*, 36: 125–133, 1935.

[12] B. Lewis and G. von Elbe, *op. cit.*, pp. 149–155.

[13] K. Schnauffer, *Soc. Automotive Engineers Jour.*, 34: 17–24, 1934.

[14] H. Rabezzana and S. Kalmar, *Automotive Industries*, 72: 324–329, 354–357 and 394–397, 1935; *ibid.*, 81: 534–542 and 632–639, 1939.

[15] W. A. Mason and K. M. Brown, *Automotive Industries*, 72: 582–584, 1935.

[16] W. A. Bone and D. T. A. Townend, *op. cit.*, p. 109.

of ignition, the burned and the unburned gas are separated by the flame front. Each elementary layer of unburned gas which is transformed by the flame undergoes physical and chemical changes which always result in a net increase in pressure or volume. Stated in other terms, regardless of whether there is a gain or loss in the total number of gas molecules, the rise in temperature upon burning is always sufficient to produce a net expansion. This expansion affects both the burned and unburned portions of the charge in proportion to their relative volumes. Obviously that expansion which takes place within the flame front must produce an increase in the velocity of the flame front in space by virtue of the outward motion imparted to the unburned gas just ahead of the flame.

Thus the movement of the flame may be likened to that of an airplane flying with a wind, the "wind" during an explosion resulting from the expansion upon burning. The speed of flame in space, like the ground speed of the plane, is the resultant of the speed in quiescent gas, or the transformation velocity, and the "wind" velocity, or speed with which the "wind" transports it bodily forward.

If a quiescent, homogeneous explosive mixture is ignited at a point, the flame begins to spread as a sphere with its center at the point of ignition.[17] It grows in diameter, maintaining the spherical shape, as long as the outward movement of the unburned gas is purely radial. The spherical shape can persist throughout the entire combustion only if the explosion vessel is a sphere with central ignition. For all containers in which some parts of the wall are nearer the flame front than others, the motion of the unburned gas will, at some stage of the burning, begin to vary from radial, and subsequently depart therefrom at an increasing rate.

Thus it is fairly obvious that the direction in which the unburned gas will move ahead of the flame front, and consequently the shape of the flame front itself, must be a function of the shape of the vessel. Ellis[18] has taken a number of beautiful successive snapshots of flame during explosions in vessels of various sorts. These furnish visible proof of the principle that the flame front always tends to assume the same shape as the container.

Most photographic records of the initial stages of explosions show that, for a brief interval following the passage of the igniting spark, the flame front has a positive acceleration in space, which results in a curvature of the flame traces on a film which was moved at a constant speed. The diagram on the right of Fig. 2 shows this early period of flame travel on a magnified scale.

The straight portion of the flame trace SF may be extended until it intersects at point A the axis SD, drawn through the spark S. The time interval SA is the increase in the duration of the explosion caused by the initial slow movement of the flame and will be termed briefly the "delay."

The curve of Fig. 2 shows that the delay increases greatly as the concentration of water vapor is reduced in equivalent mixtures of carbon monoxide and oxygen, initially at atmospheric pressure. Reducing the pressure at constant water-vapor concentration also increased the delay markedly, but quantitative measurements are difficult because of the decrease in the actinic light emitted by the explosions.

The real significance of the delay is not fully understood. The low initial speeds of flame in space appear to result chiefly from subnormal values of expansion ratio or transformation velocity, or both, which in turn appear to be asso-

[17] B. Lewis and G. von Elbe, *op. cit.*, pp. 146–147.

[18] O. C. de C. Ellis and W. A. Kirkby, "Flame," London: Methuen and Company, 1936.

ciated with the establishment of an equilibrium depth and structure of the reaction zone. The flame front must travel a distance at least as great as the depth of the reaction zone before an equilibrium structure can be established.

Pending the development of a satisfactory method for measuring either expansion ratio or transformation velocity in the very early stages of the burning, the causes of the delay period can not be fully demonstrated.

Explosions in soap bubbles. One of the simplest methods yet devised for determining transformation velocity is the soap-bubble or constant-pressure method developed by Stevens.[19] He filled soap bubbles with explosive mixtures, fired them with sparks at their centers, and photographed the resulting explosions.

High speed motion pictures of a bubble explosion[20] show that the spark produces a tiny sphere of flame which grows steadily in size, maintaining its spherical form, until all the mixture is inflamed. The soap film breaks and collapses downward before the burning is complete, so that the explosion runs its course at the essentially constant pressure of the atmosphere surrounding the bubble.

For analytical purposes the explosion in the bubble was photographed through a narrow slit which left its horizontal diameter visible. The film was carried on a drum rotating at a known, constant speed about an axis parallel to the slit. As the diameter of the flame increased, its lengthening image moved along the film and produced a V-shaped trace which constitutes a time-displacement record of the flame front, a typical example of which is shown in Fig. 3.

For most mixtures the sides of the V are practically straight, showing that the flame front travels at constant speed. This speed in space, S_s, can be calculated from the angle, α of the V, the known speed, F, of the film, and the ratio, m, of an actual distance to the corresponding distance on the film, through the relation

$$S_s = mF \tan \frac{\alpha}{2}. \qquad (1)$$

The maximum diameter attained by the sphere of hot gases may also be obtained from the film. The ratio of this final volume of the burned products to that of the original bubble is the expansion ratio, E, for the mixture when burned at constant pressure. If r is the radius of the bubble before firing and R is the final radius of the burned gas, as measured on the film, then

$$E = \frac{(mR)^3}{r^3}. \qquad (2)$$

The transformation velocity, S_t, is merely the quotient $\frac{S_s}{E}$, as could be shown if space permitted.

A careful investigation of the possibilities and limitations of the soap-bubble method[21] led to a number of refinements in the apparatus and procedure which improved the accuracy of the results considerably. Values of transformation velocity and expansion ratio were measured for various mixtures of CO and O_2, and for these mixtures diluted with argon and helium.[22]

The results show that the maximum value of transformation velocity occurs slightly on the rich side of chemical equivalence, but that values of E change very little in the neighborhood of equivalence. Argon and helium have practically the same effect on expansion ratio, but a given volume of helium produces less decrease in flame speed than a like volume of argon. The characteristics of the inert gases upon which these effects depend have not yet been definitely identified.

[19] F. W. Stevens, *Technical Report No. 176*, Nat. Advisory Committee for Aeronautics, 1923.

[20] B. Lewis and G. von Elbe, *op. cit.*, p. 147.

[21] E. F. Fiock and C. H. Roeder, *Technical Report No. 532*, Nat. Advisory Committee for Aeronautics, 1935.

[22] E. F. Fiock and C. H. Roeder, *Technical Report No. 553*, Nat. Advisory Committee for Aeronautics, 1936.

The principal advantage of the bubble method is its simplicity, since no measurement of a rapidly changing pressure is involved. Its usefulness is, however, very limited in scope, since no fuel which is soluble in the soap solution can be employed and since control of the concentration of water vapor in the explosive mixture is restricted by the presence of water in the soap film. Because of the nature of the soap film, variations in initial temperature and pressure are also not practicable.

It should be further observed that the measured values of expansion ratio are for the entire burning process, and must necessarily include not only that expansion which takes place in the flame front, but also any which may occur subsequently within the burned gas. Theoretical values of expansion ratio may be calculated from the known thermal properties and equilibrium data on the mixtures which have been studied by the soap-bubble method, if it is assumed that chemical equilibrium has been established in the sphere of hot gases having the maximum diameter. Such calculated values are in essential agreement[23] with the observations.

Explosions in tubes with large surface to volume ratio. The literature records a great many observations of spatial velocity made by firing explosive mixtures in tubes whose lengths were great compared to their diameters. To illustrate some of these results, the series of photographs shown in Fig. 4 was taken, using equivalent mixtures of CO and O_2 containing 2.7 per cent. of H_2O vapor in a glass tube approximately 1 inch in diameter and 20 inches long. In each case the tube was vertical and the lower end was closed. For pictures A, B, C and D, the upper end was also closed. For pictures E and F the upper end was opened to the surrounding atmosphere just prior to ignition, which took place at the lower or closed end in E and at the upper or open end in F. As indicated by the dashed time records (1056 dashes per second) the film speeds were the same for the first five pictures, but only $\frac{1}{2}$ as fast for picture F. The first glance at Fig. 4 shows that one of the principal difficulties encountered in the study of explosions in tubes is the vibratory character of the flame motion.

In all of the flame records shown, the speed of the flame is low compared to the velocity of sound, so that the pressure gradients which can exist are local in character and comparatively small. The effects of changes in temperature and total pressure upon transformation velocity are likewise small until long after the vibration has begun. Therefore the only factor which can decelerate the flame in space is a reduction in the velocity of the unburned gas away from the point of ignition. It is believed that, for the closed tube, such a reduction in gas velocity, and in picture A even a complete reversal in the direction of motion, may have been produced in the following manner.

Prior to the start of vibration, the expanding flame initiates a pressure wave which outdistances the flame front because it moves through the unburned gas with the velocity of sound. This pressure wave is reflected back from the upper end of the tube and returns to meet the flame. As soon as this pressure front enters the burned gas its velocity undergoes a sudden large increase, since the density of the hot gas is about $\frac{1}{10}$ that of the unburned gas. This rapid increase probably accentuates the rarity of the following stratum. Into this rarified stratum, the unburned gas ahead of the flame will expand and thus acquire a backward component which either retards or reverses the movement of the flame front, and the first wave appears in the flame trace.

The amplitude of a given irregularity in the flame trace would thus appear to

[23] B. Lewis and G. von Elbe, *op. cit.*, pp. 321–326.

depend primarily upon the difference in the velocity of sound in the burned and unburned gas, which in turn is a function of the difference in density.

Consider now the effects of initial pressure upon the character of the vibrations, as shown in A, B and C of Fig. 4, for which all conditions were the same except that the initial pressures of the explosive mixtures were 1, $\frac{2}{3}$, and $\frac{1}{3}$ atmospheres, respectively. In the first place, the adiabatic temperature rise in the unburned gas, for any given position of the flame front, increases as the initial pressure is decreased. Secondly, it may be seen from the photographs that the amount of actinic light radiated by the burned gas is less the lower the pressure. This probably means that the temperature of the burned gas is less for the explosions from low pressures, which in turn is to be expected from the longer molecular free path and consequent greater percentage heat loss to the walls nearby.

Thus it appears that, for identical pressures in the explosion vessel, the lower the initial pressure the higher is the temperature of the unburned gas and the lower is that of the burned gas, both conditions tending to reduce the magnitude of the change in the velocity of the reflected pressure wave at the flame front. Thus the amplitude of the vibration of the flame front decreases with initial pressure. Similarly, since the average temperature of the burned gas is less when the initial pressure is low, more time is required for the wave traveling toward the point of ignition to reach this end of the tube and return again to catch and accelerate the flame front. The period of the vibrations of the flame during runs from low initial pressure is therefore greater, as may be seen in the photographs.

Pictures A, B and C also illustrate the fact, already mentioned, that the duration of the delay period becomes greater as the initial pressure is decreased. While in A the flame can be seen to move away from the point of ignition immediately after the passage of the spark, it moves more slowly in B, and in C there is an interval of about 0.001 second subsequent to the spark in which no flame trace is visible even on the original negative.

For picture D, the explosive mixture initially at a pressure of 1 atmosphere, was fired simultaneously at both ends of the closed tube. In this case the time required for the flames to traverse all the charge was approximately half of that required when the ignition was at one end only. The unburned gas appears to have vibrated more or less as a unit, since the crests of one flame trace are about simultaneous with the troughs of the other.

For picture E the tube was filled with explosive mixture to a pressure of 1 atmosphere and the upper end was opened to the surroundings just prior to firing. The only retrogression of the flame front occurred after it had traveled about three-fourths the length of the tube. Since the nearest solid reflecting surface was the ceiling of the room, about seven feet above the open end of the tube, it is probable that the retrogression is the result of the behavior of the tube as an open organ pipe.

For picture F the tube was again filled to a pressure of 1 atmosphere, the upper end was opened, and a spark gap consisting of small nickel wires was introduced. Only these two wires were in a position to disturb the free egress of the burned gas. The film speed was reduced to one fifth that employed for the other records of this series. Vibrations of the flame front are visible throughout the entire flame trace, but in similar records made by igniting the charge with a flame instead of a spark these vibrations do not always appear until later in the burning process. The wires of the spark gap

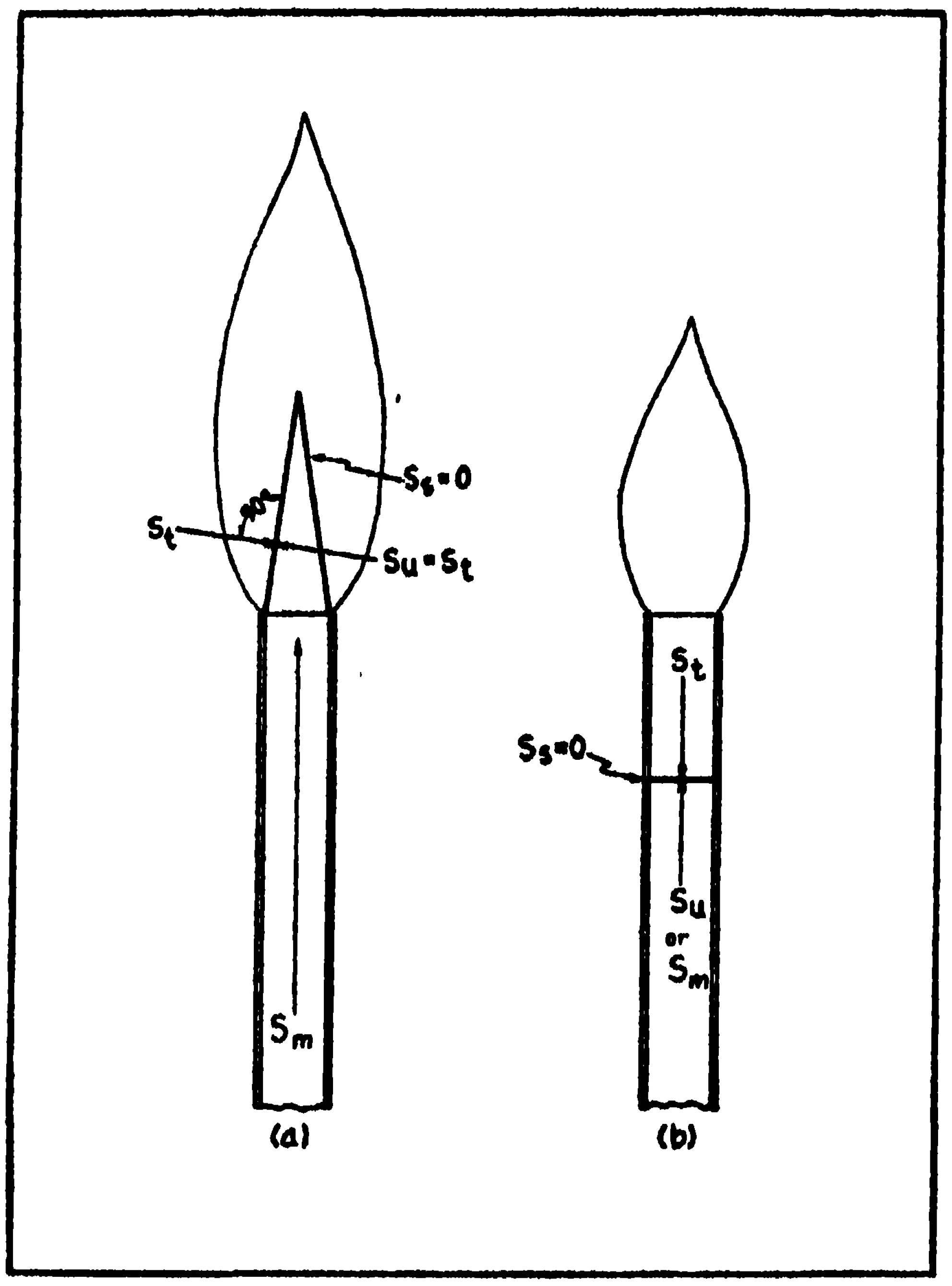

FIG. 1. DIAGRAMMATIC REPRESENTATION OF BUNSEN FLAMES IN A HYPOTHETICAL BURNER.

may therefore have been responsible for the early vibrations in picture F.

The general forward velocity of the flame, without regard for the vibration, is, in this case, about 150 cm per second, which, barring wall friction and heat loss, should be the transformation velocity. The actual value of S_t for this mixture, as observed by other methods, is very close to 100 cm per second, thus showing that this particular open-end tube does not give reliable values of S_t.

The reason for the higher flame speeds in the first five pictures compared to that in picture F is, of course, that all the expansion in the former took place behind the flame front and was effective in moving the unburned gas in the direction of the flame travel. However in F the only motion imparted to the unburned gas is that resulting from the reaction of the walls to the escape of the burned gas.

It is hoped that the pictures constituting Fig. 4 have illustrated the major possibilities and limitations of the tube as a vessel in which normal explosions may be observed.

There are many recorded values[24] of flame speed measured in open-end tubes. Such values of spatial velocity have never been sufficiently free from effects inherent in the apparatus to be considered true transformation velocities. This fact is further emphasized by the experimental facts themselves which show that the observed spatial velocity for a given mixture may increase many fold with tube diameter, and that different values are observed when the propagation is in an upward, downward or horizontal direction.

The relative effects of both wall friction and heat loss to the walls decrease as the tube diameter is increased, so that the observed spatial velocities should approach the transformation velocities for large tubes. In such tubes, however, the difficulty of uncertain flame shape is introduced, since ignition is hard to accomplish simultaneously over a large surface.

Explosions in large cylinders and spheres. In any explosion in a closed vessel many complications are introduced by the continuously and rapidly rising pressure. However, much useful information has been obtained by conducting explosions in such vessels without photographing the flame and without measuring the rise in pressure. In most of these experiments it is only necessary to determine whether or not there has been an explosion, and the eye or ear may be adequate.

The more important results of such experiments are (1) the so-called "ignition temperature," or temperature above which the reaction becomes self-propagating; (2) the ignition characteristics, and (3) the concentration limits of the self-propagation of flame.

[24] W. A. Bone and D. T. A. Townend, *op. cit.*, chaps. 11–14.

The spatial velocity of flame in closed containers may be measured by the methods previously described. In such vessels, however, this velocity is highly dependent upon the shape, so that numerical values are of little use unless the movements of the unburned gas can also be determined. An exception should be noted in case all points on the walls of the explosion vessel are at a considerable distance from the spark gap. Soon after ignition in such large containers the spatial velocity attains a constant value which is independent of the characteristics of the container, and is a function only of the expansion ratio and transformation velocity of the particular explosive mixture at the initial temperature and pressure. Practically identical values of the constant spatial velocity of flame in mixtures of CO and O_2 have been observed by the author for explosions in soap bubbles,[25] in a large glass cylinder[26] and in a steel sphere.[27]

When it is desired to follow the entire combustion process from ignition to the walls of the vessel, it is obvious that a spherical vessel with central ignition offers the most promise, since the movements of both flame and gases are symmetrical and may therefore be more readily and more completely analyzed. In other words the spherical container with central ignition seems to offer the greatest chance of minimizing the specific effects of the apparatus in which the burning takes place upon the observed quantities.

Studies of explosions at constant volume are of greatest use only when provision is made for measuring the rapid rise in pressure which results from the burning. Some years ago the primary object of the measurement of explosion pressures was the determination of the mean heat capacities of diluent gases between the initial and final temperatures. Subsequently this method of measuring heat capacity was largely replaced by more reliable spectroscopic methods.

Hence the more recent measurements of explosion pressures have had, as their primary goal, the determination of expansion ratio, transformation velocity, and other quantities which appear to be indices of the power, performance, and economy inherent in the explosive mixtures.

No discussion of explosions at constant volume would be complete without some mention of the pressure indicators which have been used. Those devices yielding pressure-time or pressure-volume data may be classified as (1) optical indicators; (2) balanced-pressure indicators; (3) sampling indicators; (4) micro-indicators, and (5) electrical indicators, according to the principle on which they operate.

In most of these instruments a flexible

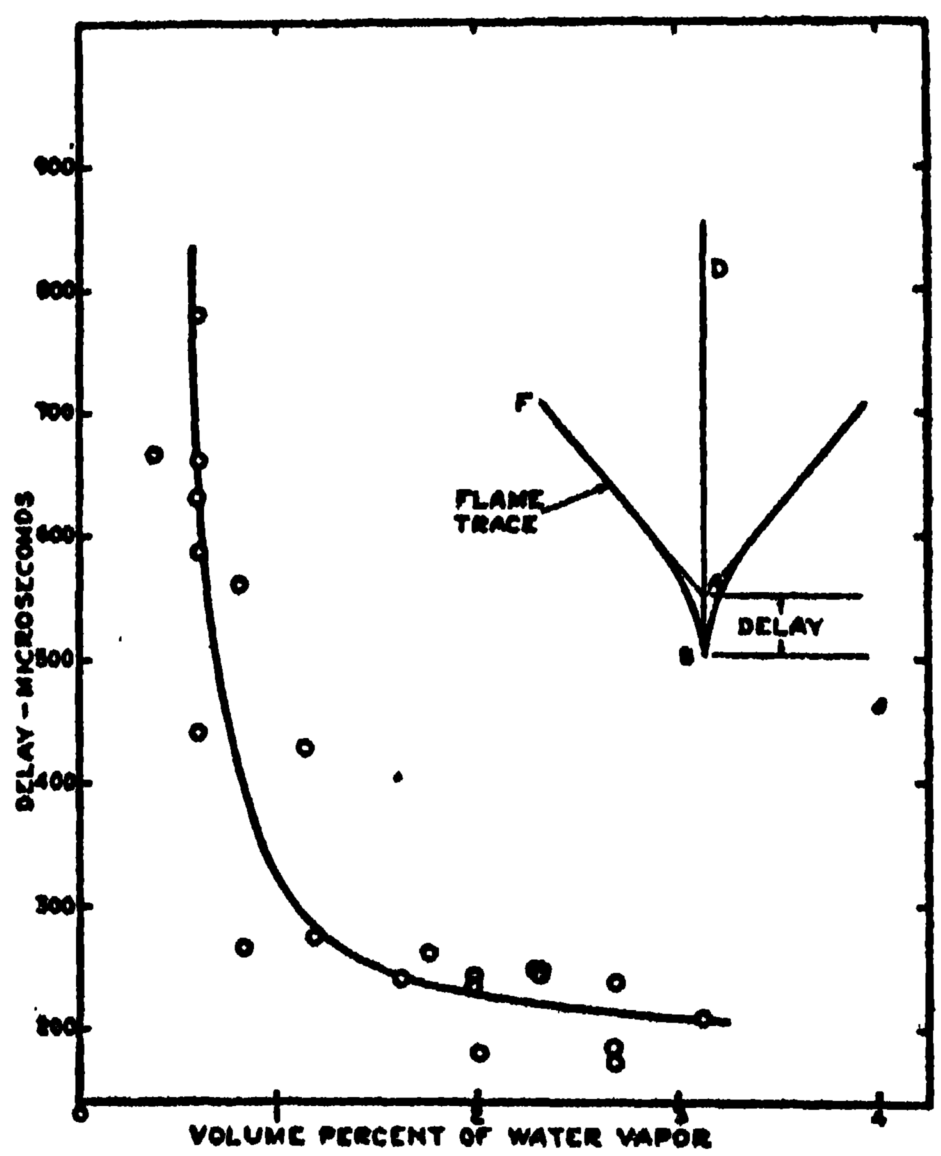

FIG. 2. EFFECT OF WATER VAPOR ON THE DELAY PERIOD IN EQUIVALENT MIXTURES OF CO AND O_2.

[25] E. F. Fiock and C. H. Roeder, *Technical Report No. 532*, Nat. Advisory Committee for Aeronautics, 1935.

[26] *Ibid., Technical Report No. 553*, 1936.

[27] E. F. Fiock, C. F. Marvin, F. R. Caldwell and C. H. Roeder, *Technical Report No. 682*, Nat. Advisory Committee for Aeronautics, 1939.

diaphragm is used as the pressure-sensitive element. Many different methods, both mechanical and/or optical, have been devised for magnifying and recording the motion of the diaphragm. In other types the operation of a light piston or valve shows when the explosion pressure has reached a previously selected and measured value. Still other types make use of the effect of the explosion pressure upon the resistance of an element such as a carbon pile, upon the capacitance of an appropriate condenser, and upon the electromotive force, or more exactly upon the piezo-electric properties of certain crystals such as tourmaline or quartz. In the latter instances a flexible diaphragm usually protects the sensitive element from direct contact with the flame.

In all these instruments a compromise must be made between the time required to accelerate the moving parts and their sensitivity to change in pressure. For example an indicator appropriate for measuring explosion pressures with sufficient accuracy to permit calculation of transformation velocity must have a much higher sensitivity and over-all accuracy than the more rugged instrument suitable for yielding the ordinary engine-indicator cards. The choice of an indicator must, therefore, involve careful consideration of the operating conditions and the required accuracy of the pressure measurements.

Recently a series of measurements[28] using a spherical bomb with central ignition and a window through which the progress of the flame could be photographed, and with six diaphragm-type pressure indicators was conducted at the National Bureau of Standards, using the fuels CO, normal heptane, iso-octane and benzene.

Fig. 5 is a diagrammatic representation of the spherical bomb with its window and of typical flame traces for bomb and soap bubble. When a spark occurs at the center of the bomb, a sphere of flame starts to spread exactly as in the constant-pressure explosion. However, the walls of the bomb soon resist the outward flow of gas set up by the expansion, and the unburned charge is compressed instead of merely being pushed away by the advancing flame front. Thus the expanding gases can not push the flame front outward as fast or as far as in the bubble explosion. As a result of the steadily decreasing outward gas velocity, the flame front travels more slowly as it approaches the walls, even though it is propagating into the compressed and heated unburned charge at an ever-increasing speed.

The slopes of the flame traces shown in Fig. 5 constitute a direct measure of the speeds of flame in space. The slope of the trace of the flame in the bomb gradually decreases from the constant value of that in the bubble until it reaches a value at the wall which is a measure of the transformation velocity in the last portion of the charge to burn. This condition must always prevail since the last of the gas to burn can not move beyond the walls, and is, therefore, essentially at rest when traversed by the flame.

Fig. 6 is a reproduction of a typical explosion record, the fuel in this particular case being benzene. Adjacent to the flame trace is the time record consisting of a series of dashes of known frequency. Beyond are six lines constituting the pressure record. The start of each line indicates the instant at which the explosion pressure reached the value for which an indicator had previously been set. The electrodes at the spark gap photograph as a thin dark line which served as an axis of zero flame displacement. The light streak extending across the figure is a still picture of a fixed slit in the camera, the neon lights operated by the pressure indicators, and the firing

[28] *Ibid.*

spark. This part of the record was made to permit the evaluation of small corrections for lack of alignment. From such simultaneous time-displacement and time-pressure records, a number of the burning characteristics for comparable mixtures of the above mentioned fuels were derived.

In explosions of CO and O_2 the rise in pressure is approximately the same for a given mass of mixture inflamed, regardless of initial pressure. This was to be expected from theoretical considerations since the only difference must result from secondary effects of temperature and pressure upon the chemical equilibrium.

During the early stages of the burning of the three hydrocarbon fuels in theoretical proportions with O_2 there is likewise no measurable difference in the pressure rise produced when a given fraction of the charge is inflamed. Later in the burning small differences do appear in the order of the hydrogen-carbon ratio of the fuels, as might be anticipated from the thermal properties of the products of combustion.

In all the explosions studied there is a general increase in the transformation velocity as the temperature and pressure of the unburned charge rise because of adiabatic compression by the advancing flame.

In the explosions of CO and O_2, for which it was possible to calculate the independent effects of temperature and pressure, both these variables appear to influence the transformation velocity. Some uncertainty in the magnitudes of the effects arises from the possibility that other factors, associated in some obscure way with the stage of the burning, may influence transformation velocities to an unknown extent.

For the hydrocarbons, the transformation velocity is highest for the benzene, and lowest for the iso-octane, with the n-heptane intermediate. Addition of ethyl fluid to the heptane produced no appreciable change in flame speed. Thus there appears to be no relation between transformation velocity under the conditions of the experiments and the tendency of the fuels to knock in an engine. In fact a thorough examination of all the characteristics of normal burning reveals that none can be correlated with tendency to knock. The behavior of all three fuels in the bomb is so nearly the same that high accuracy of the measurements is necessary to show any differences at all in those characteristics which are independent of the apparatus.

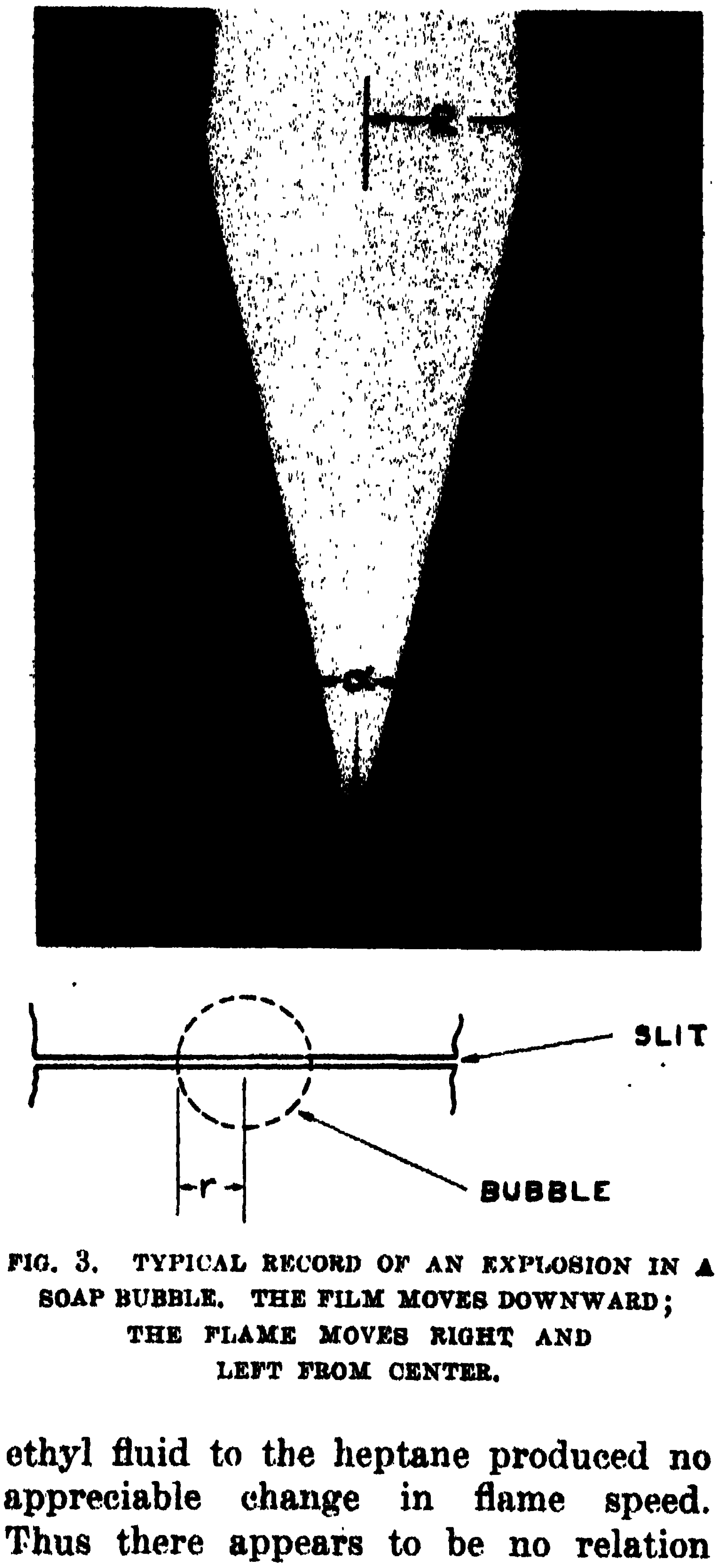

FIG. 3. TYPICAL RECORD OF AN EXPLOSION IN A SOAP BUBBLE. THE FILM MOVES DOWNWARD; THE FLAME MOVES RIGHT AND LEFT FROM CENTER.

FIG. 4. TYPICAL RECORDS OF EXPLOSIONS IN CLOSED- AND OPEN-END TUBES.

In all the explosions the rise in pressure for a given mass of charge inflamed was considerably less than would be expected from calculations based on thermal data and the assumption that chemical reaction goes to equilibrium in a very thin reaction zone. The results therefore indicate that the burning is not completed in a shallow zone, but that reaction and heat liberation continue for some time after the flame front has passed.

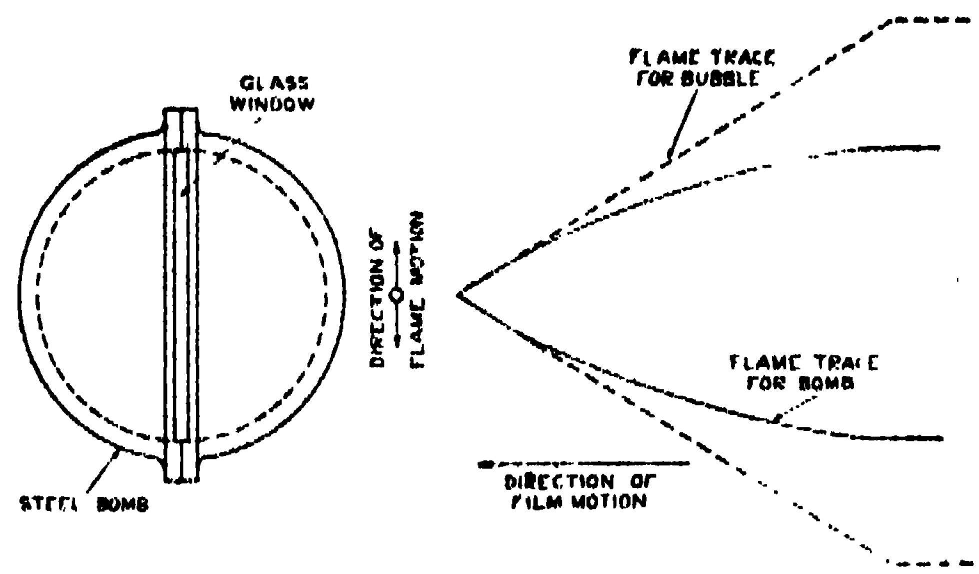

FIG. 5. DIAGRAMMATIC REPRESENTATION OF A SPHERICAL BOMB AND TYPICAL FLAME TRACES FOR BOMB AND SOAP BUBBLE.

Further visual evidence of this continued evolution of energy within the inflamed gases, sometimes called afterburning, was obtained by photographing the gas movements within the sphere of flame. In one such experiment eight human hairs, more or less symmetrically spaced with respect to the spark gap, were stretched across the bomb. At the center of each hair, in the line of vision of the camera through the window, a few finely ground particles of black gun powder were attached with very dilute shellac.

Fig. 7 is a photograph of a $CO-O_2$ explosion with such an arrangement inside the bomb. The hairs seem to offer no resistance to the motion of the flame, while the powder seems to ignite as soon as it is touched by flame, and then to burn very brightly. It can be seen that the hot gases from the powder begin to move at once toward the center of the bomb. This movement continues for some time after the flame has reached the wall of the bomb, as indicated at point A in the photograph. The outward motion of the powder flame in the regions marked B is probably the result of contraction due to cooling at the wall.

There are two possible effects which could cause the flame gases to move toward the center, namely expansion in the gases which surround them, and contraction in the gases which they enclose.

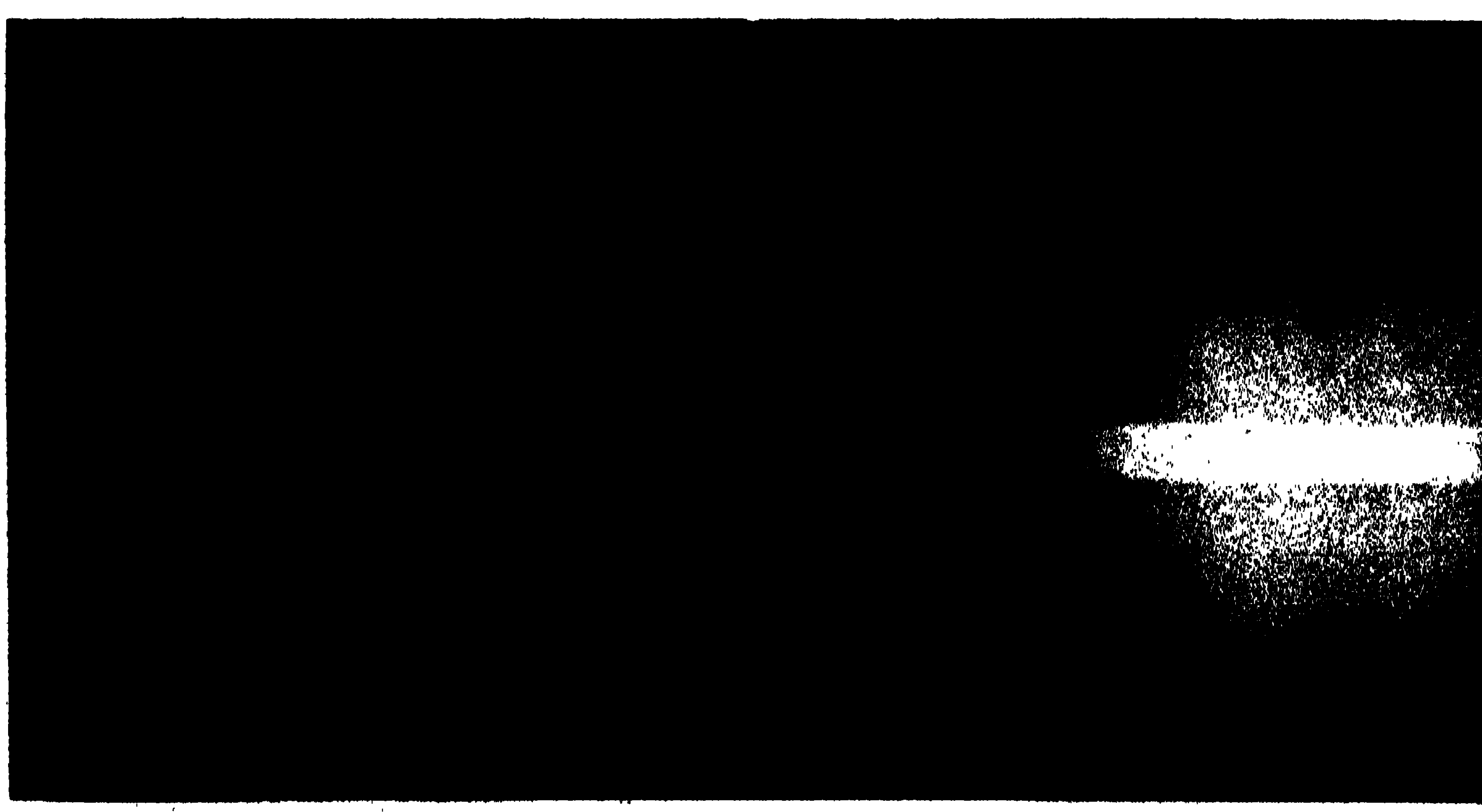

FIG. 6. TYPICAL RECORD OF AN EXPLOSION IN A SPHERICAL BOMB OF CONSTANT VOLUME.

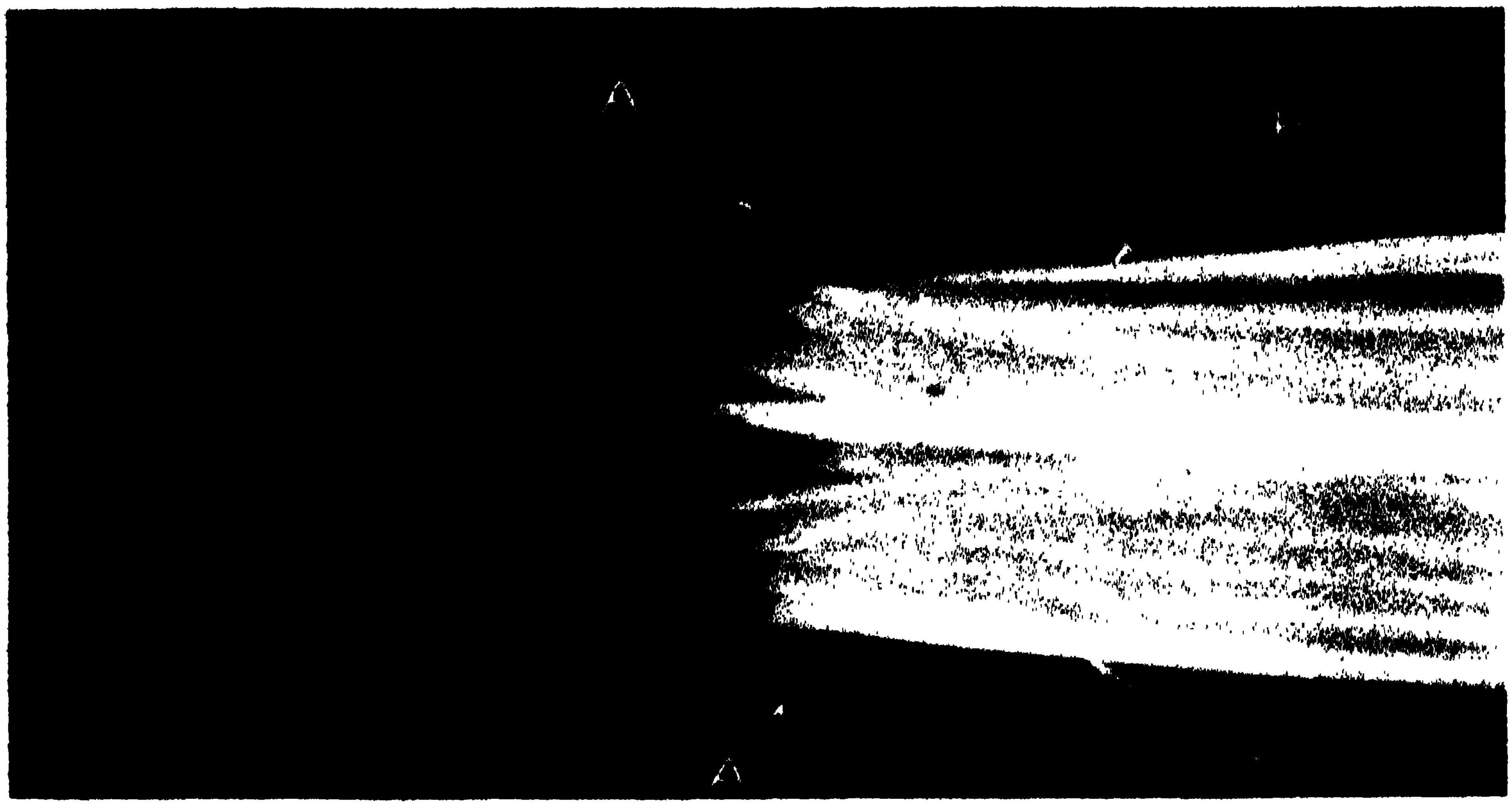

FIG. 7. RECORD OF AN EXPLOSION IN A SPHERICAL BOMB, SHOWING MOVEMENTS WITHIN THE BURNED GAS.

The latter could occur only if the gas near the center were losing heat by radiation at a seemingly improbable rate. It is therefore believed that the continued movement of the flame gases toward the center, after the flame hits the wall, indicates continued expansion in an outer shell of gas which has already been traversed by flame, and that Fig. 7 is thus visible evidence of afterburning. It is further believed that the inward movement of the central flame gas beyond point A can not be due to burning of the powder because such small amounts were used and because the same movement was observed in each of a number of similar explosions where the powder was present at only one instead of eight points.

Lewis and von Elbe[29] calculated values of transformation velocity for ozone-oxygen explosions in a spherical bomb from the time-pressure records alone. These investigators have since referred to a new spherical bomb[30] in which there is provision for taking flame records simultaneously with the pressure records, although actual explosion data with this apparatus have not yet been published.

[29] B. Lewis and G. von Elbe, *Jour. Chemical Physics*, 2: 283–290, 1934.
[30] B. Lewis and G. von Elbe, *Jour. Chemical Physics*, 7: 197, 1939.

(*To be Concluded*)

SCIENTISTS LOOK AT ASTROLOGY

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PUBLIC interest in astrology has grown rapidly during the past decade, due in no small measure to the general misapprehension that exists in the minds of many about the standing of astrology as a "science." Astrologers have made skilful use of this confusion and, by the use of pseudo-scientific terms, have succeeded in gaining some degree of public respect. It is significant that it is a general practice on newsstands to place sound popular scientific and engineering journals on the same shelf as the astrological magazines. The confusion is not limited to the less-educated sections of our population; a few months ago one of the country's foremost public libraries gave in its monthly bulletin a list of recent acquisitions in astronomy and astrology in a section headed "Science." There is hardly an astronomer who has not been approached on more than one occasion with a request for the preparation of a horoscope.

What have scientists done to correct such misconceptions? Individuals have occasionally voiced a protest, but active concern in the spreading of astrology has generally been considered below the dignity of scientists. Yet it can hardly be denied that it is one of the functions of scientists in a democracy to inform the public about the nature and background of a current fad, such as astrology, even though to do so may be unpleasant.

Astronomically minded members of the Boston and Cambridge Branch of the American Association of Scientific Workers, aided by some of their colleagues in other parts of the country, recently formed a committee for the investigation of astrology, with B. J. Bok, *chairman*, and Mrs. M. W. Mayall, *secretary*. This committee is releasing simultaneously with this issue a first report in which a general survey is given of several problems related to astrology. We present here a summary of the report, covering such topics as the accepted techniques of astrologers, the history of astrology, the extent to which it has spread, the attitude of scientists, and the legal aspects of the problem.

I. THE HOROSCOPE AND ITS INTERPRETATION

In the technique usually employed by astrologers the horoscope of an individual at the time of his birth plays an all-important role in astrological predictions. Figs. 1 and 2 show how such a horoscope is prepared. Fig. 1 shows how the horizon and celestial meridian divide the celestial sphere for a particular location into four equal parts. Each quarter section of the sphere is again divided into three equal sections by great circles passing through the north and south points on the horizon. The twelve sections thus formed are called "houses" and the points of intersection of their boundaries with the ecliptic are called the "cusps." The exact location of the houses and the cusps in the horoscope of a given individual can be determined only if the time of birth and the longitude and latitude of the place of birth are all accurately known. Comparatively small errors in these basic data

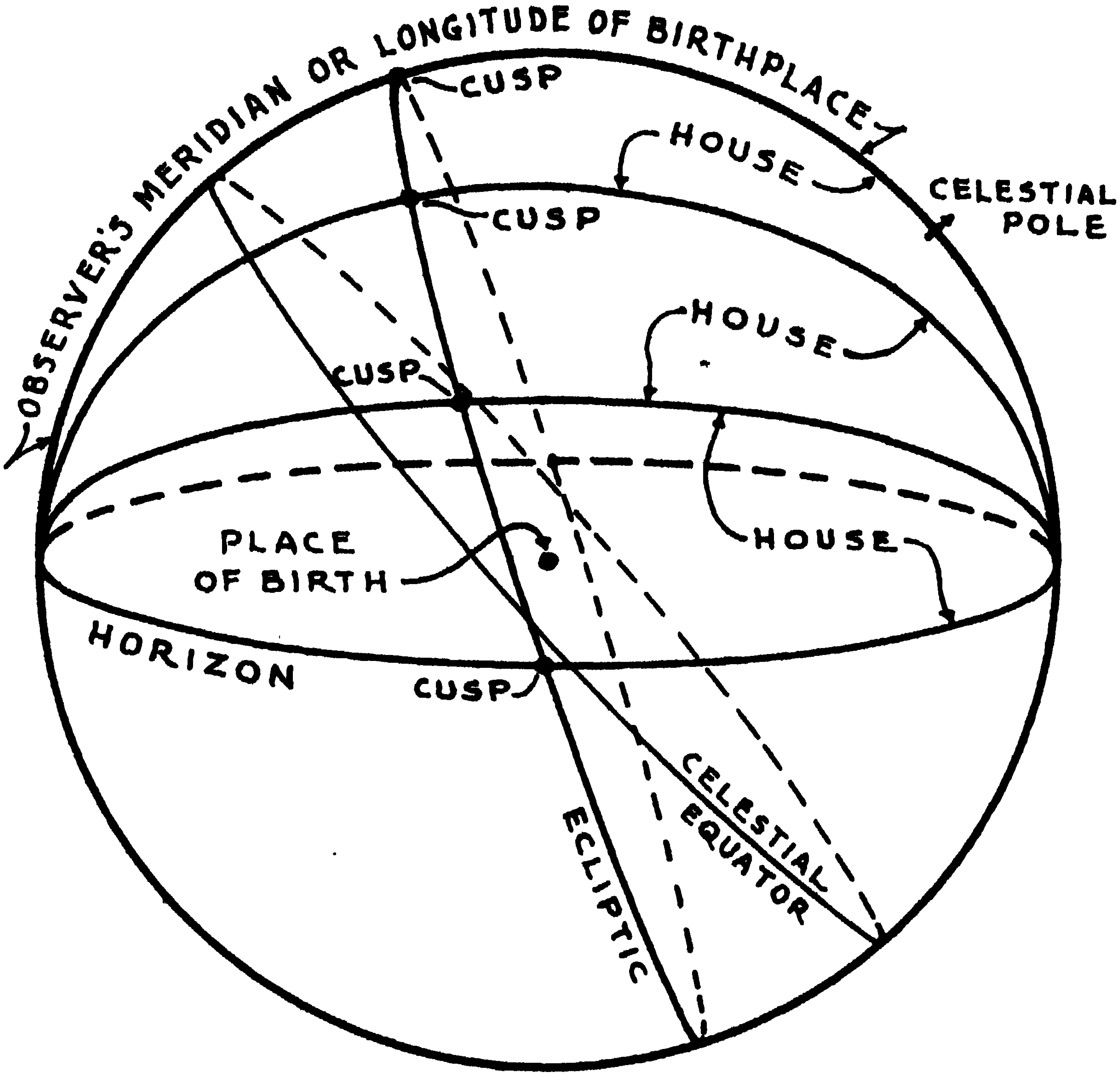


FIG. 1. CELESTIAL SPHERE DIVIDED INTO TWELVE PARTS
THE TWELVE SECTIONS FORMED BY THE GREAT CIRCLES ARE CALLED "HOUSES," AND THE POINTS OF INTERSECTION OF THEIR BOUNDARIES WITH THE ECLIPTIC ARE CALLED "CUSPS."

may have a considerable influence on the relative positions of the planets and cusps.

Fig. 2 is a conventional type of horoscope. The outer circle of the wheel or tire represents the ecliptic and its spokes mark the houses. The houses are numbered as indicated and, with the aid of an astronomical ephemeris, we can now plot the positions of the sun, moon and planets in the houses at the time of birth. The positions of the cusps in the zodiacal constellations are shown by the signs and degrees in the tire.

The interpretation of a horoscope is carried out according to a set of more or less standardized rules, but each expert has developed his or her own system. Each "house" is associated with various matters and each planet, supposedly acting as a center of force, exerts a particular influence, depending upon its position in the horoscope. The relative positions of the planets and their "aspects" play an important part in the interpretation of a horoscope. Standard treatises on astrology, such as the books of Alan Leo, give the significance of each particular aspect, at the time of birth and in later life.

Many astrologers use the system of secondary progressions as the ideal technique of prognostication, according to which each successive day after birth represents a year in the life of a subject. There is, however, considerable disagreement about the value of progressions among leading astrologers of to-day. One of them has stated flatly that "progressions are non-existent."

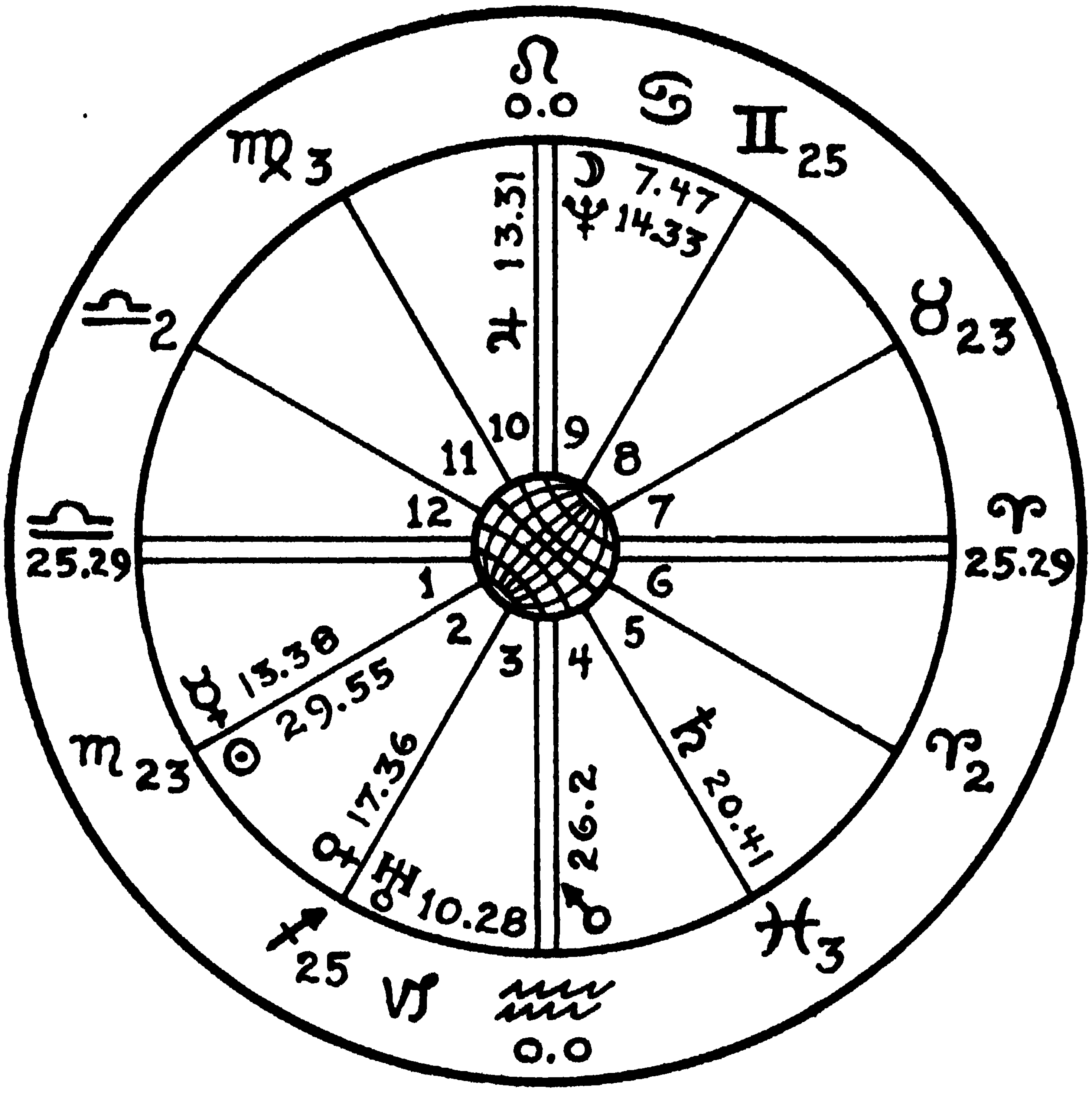


FIG. 2. CONVENTIONAL TYPE HOROSCOPE OF BIRTH

NOVEMBER 23, 1907. 4 A.M. E. S. T. 40° 43′ N. 73° 58′ W. OUTER CIRCLE REPRESENTS ECLIPTIC AND ITS SPOKES MARK THE "HOUSES." SIGNS AND DEGREES MARK THE "CUSPS."

II. History

The earliest records of astronomy in our Western tradition are of Babylonian origin. The researches of Neugebauer have shown that astrology made its appearance only after astronomy had reached a high level of development. Judicial astrology appeared in Babylonia after 600 B.C., long after the Babylonian astronomers had developed their astronomical tables and ephemerides, calendars and lunar eclipse theory, and long after the discovery of the Saros cycle in solar eclipses.

There existed no judicial astrology during the high periods of civilization in Egypt and it was only during the Hellenistic period, when Egyptian civilization was moribund, that Babylonian astrology was introduced. The Greek astronomers did not concern themselves with astrology until Hellenistic times, when, largely through the influence of Berosus, a school for astrologers was established on the island of Cos.

Ptolemy, the last of the important Greek astronomers, was interested in astrology. Just as Ptolemy's "Almagest" became the standard reference in astronomy, so did the same author's "Tetrabiblos" become the bible of astrology for Islam and the Latin West. Our present-day astrology goes back to Ptolemy. Ptolemy, who flourished at the end of a period of about fifteen hundred years of astronomical development, was apparently the only Greek astronomer of first rank to be connected with astrology.

Astrology threatened to take complete possession of all classes of society in the

Roman world. Cato the Elder and Cicero attacked astrology, but there is no evidence that they had much influence on their contemporaries. Although there were edicts against astrologers, notably in the reigns of Augustus, Domitian and Hadrian, nevertheless their prophecies were feared and they were consulted secretly. The condition is curiously parallel to that which exists in Germany at the present time.

The Roman Catholic Church was vigorously opposed to astrology. St. Augustine, who admitted in his "Confessions" that before his conversion he had been attracted to astrology, was its most articulate and vehement opponent. The opposition to astrology by the Catholic Church has persisted through the ages. The only recorded lapses are toward the end of the middle ages, during the centuries that preceded the birth of modern natural science. The attitude of the Catholic Church is summarized in the words of a modern Catholic writer, who states: "The Catholic Church condemns astrology as a pagan superstition which by encouraging fatalism leads to the denial of Divine Providence."

With the fall of the Roman Empire, astrology came to an end in the West for about five hundred years. The return of astrology in the Latin West came with the introduction of Arabic science in the eleventh and twelfth centuries.

When the Arabs took over Greek science, they also acquired the astrology which had developed in the Hellenistic period; and in the great period of Arabic culture (A.D. 900–1100) astrology became associated with alchemy, medicine, astronomy and mathematics. It has been suggested that most of the Arabic observatories were erected primarily for astrological purposes and that their astronomical use was only incidental, but this has not been confirmed by modern historical research. The main reason for the building of these observatories, including the famous one at Bagdad, was to determine the direction toward Mecca so that the faithful could face it at the hours of prayer.

In the early medieval period, astrology was reintroduced into the Latin West principally through Arabic medicine. It had little influence during the twelfth century, but it went rapidly forward during the thirteenth century and attempted to gain recognition as a "science" by claiming that it was based on cosmological principles. The tolerance of some forms of astrology by church authorities made it possible for astrologers to establish themselves, even to holding professorships in several Italian universities.

During the late Middle Ages and the early Renaissance the opposition to astrology was vigorous, within the church and without, by mathematicians and scientists, including Oresme, Henry of Hesse, Albert of Saxony, and by humanists like Petrarch and Pico della Mirandola. But astrology had gained such a foothold that astronomers were often forced to earn their living by astrology while carrying on their work as best they could. The case of Kepler is an outstanding example. To begin with, Kepler had great difficulty in obtaining an appointment because he was a Protestant and a Copernican but, when he did get a position as lecturer on mathematics at the poor academy at Gratz, one of his duties was the preparation of the yearly almanac containing weather predictions and astrological information. Later, when he was appointed as imperial mathematician at Prague to succeed Tycho Brahe, his financial troubles were not at an end; and in 1628, two years before his death, when his salary was three years in arrears, he took to drawing up horoscopes for the astrologer-soldier Wallenstein as a means of supporting himself and his dependents. Well might Kepler say "Mother Astron-

omy would certainly have to suffer if the daughter Astrology did not earn the bread." In spite of this financial necessity, Kepler kept his astronomical work free from astrology. Tycho Brahe is the only astronomer of the first rank who completely fused his astronomy and his astrology.

The religious revival accompanying the Reformation and the Roman Catholic Counter-Reformation was the most important influence in putting an end to this period of astrology. Astrology still continued to "hang on," as we know from the diatribes of Jonathan Swift, the jibes of Benjamin Franklin and the wrath of Increase Mather against individual astrologers. But its power was broken, and it did not win any marked increase in public interest until our own time.

In this historical summary several interesting points emerge: astrology has flourished in periods of high scientific development rather than in low periods, and likewise in periods when religion and philosophy were in eclipse. Also, astrology has made only practically negligible contributions to science; indeed, its prevalence has been actually harmful. In the middle ages, when students were flocking to astrology lectures, astronomers were having a hard time to earn their living from scientific work. On medicine, astrology had a strangling influence, for physicians gave up diagnosis from the symptoms and case history and relied on horoscopes to tell them why the patient was ill, what drugs to prescribe and what was the favorable time to apply the remedies. Astrology hindered the development of chemistry, because it was only after alchemy had been purged of astrology and other superstitions that chemistry grew as a separate discipline. The most striking fact is that astrology is now trying once more to gain recognition as a science by the use of methods that are reminiscent of those used with success during the middle ages.

ASTROLOGERS' BOOTHS
IN LAHORE, INDIA.

III. Press, Magazines and Advertising

A large percentage of the newspapers of the United States publishes either daily or monthly columns on astrology. These columns might be expected in newspapers sold to the less-educated portion of the population and in the sections of the country where superstition is widespread, but a survey shows that there are hundreds of such newspapers that carry no astrological data whatever. It is in the large centers of population that astrological columns are most prevalent. Most of the public libraries in large metropolitan areas have on file more than a hundred representative newspapers selected from all over the country. On the average about 20 per cent. of the newspapers on file carry astrological columns.

The condition in New York City is more or less typical. Only two out of

"UTRIUSQUE COSMI . . . HISTORIA" ROBERTO FLUD, OPPENHEIM, 1617. TITLEPAGE. A COMPENDIUM OF ASTROLOGY AND MAGIC WITH SPECIAL EMPHASIS ON THEIR USES IN THE DIAGNOSIS AND CURE OF THE ILLS OF THE HUMAN BODY. THE SECTIONS DEVOTED TO ARITHMETIC, GEOMETRY, ETC. ARE OF NO SCIENTIFIC IMPORTANCE. THIS WAS AN IMMENSELY POPULAR WORK AND WAS PRINTED IN MANY EDITIONS.

nine general newspapers published in Manhattan, the *Daily News* and the *Journal-American*, publish astrological columns; but the *News* alone has the largest circulation of all newspapers in the country, about 1,880,000 daily and about 3,380,000 on Sunday, according to 1939 averages. The *Journal-American*, with 609,000 daily, has the largest circulation among the local afternoon papers. Thus the number of readers exposed to these columns is much greater than the proportion of papers (2 out of 9) carrying them would indicate.

Some of the leading newspapers of the country are now printing astrological columns. In the eastern part of the United States the list of distinguished offenders includes the *Philadelphia Inquirer*, the *Times-Herald* of Washington, D. C., and the *Boston Traveler*. In the southeast the *Memphis Commercial Appeal*, the *Charlotte Observer*, and the *Atlanta Constitution* all carry astrological columns. The *News* and the *Plain Dealer* in Cleveland, the *Ohio State Journal*, Chicago's *Herald and Examiner* and the *Daily Tribune* have astrological features. In the San Francisco area two of the four large newspapers carry astrological columns and two do not. Advertisements by astrologers are regularly printed by many of the newspapers that do not refer to astrology in their news sections. Some news syndicates have occasionally released stories with astrological predictions.

The code of standard astrology, to which the great majority of the country's astrologers are supposedly adhering, states that "a precise astrological opinion can not honestly be rendered with reference to the life of an individual unless it is based upon a horoscope for the year, month, day and time of day plus correct geographical location of the place of birth of the individual . . ." This statement alone renders all daily forecasts in newspapers void. The supposedly individual horoscopes that can be obtained by writing in and enclosing twenty-five cents are in reality frequently only copies from a relatively small number of master horoscopes.

The newspapers are by no means the only offenders. Weekly and monthly magazines with a nation-wide distribution have printed articles by leading astrologers. On May 12, 1940, the *American Weekly*—which claims the largest circulation of any magazine in the world—began a series of front-page articles on astrology by "Hollywood's astrologer" Norvell. It is, however, encour-

aging that *Good Housekeeping* has just taken a firm stand against astrology. The Federal Communications Commission has ruled astrologers off the air waves after protest by the American Astronomical Society and the American Society of Magicians.

Hollywood appears to be a veritable astrologer's paradise, and in a quieter way Wall Street has proved a fertile field for astrological activity. Thus it is quite apparent that the influence of astrology is by no means limited to persons with salaries in lower income brackets.

Prominent among the strictly astrological magazines are: *American Astrology, Horoscope, Astrology Guide, Wynn's Astrology, World Astrology* and *Astro-Digest*. *American Astrology* is said to have a circulation in excess of 100,000. The average newsstand carries at least four or five different astrological magazines. The dime stores have succumbed to the astrological craze. Modern automatic scales produce tickets with the weight of the victim on one side and astrological advice on the back.

Astrology has made considerable inroads in advertising. The Better Business Bureaus have exposed many of the schemes used by astrologers, but in spite of their effectiveness they have not succeeded in eliminating astrology as an aid to salesmanship.

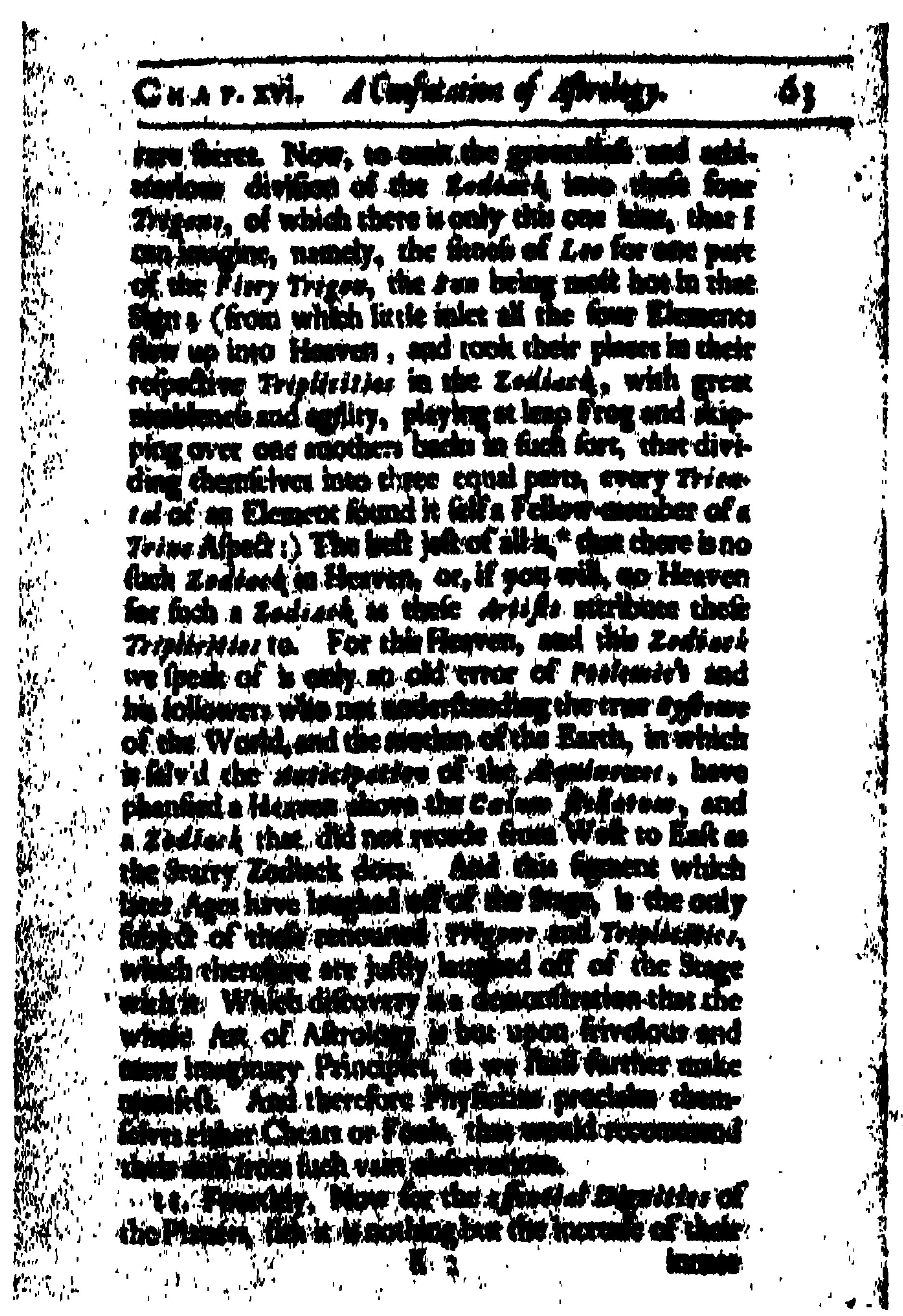
IV. Legal Aspects

Many states have laws prohibiting the practice of astrology. According to *American Jurisprudence* (Vol. 23, p. 711) "the offense of fortune telling is generally held to be a misdemeanor. Under many statutes fortune tellers are declared to be vagrants and disorderly persons, and it has been said that such persons are without any property rights in a name or appellation, which a court of equity will protect."

In the State of New York the legislature "has signified its disbelief in human power to prophesy human events." "Any prediction of human events for hire is prohibited by subdivision 3 of section 899 of the code of criminal procedure." (253 N.Y.S. 836.) The availability of astrological literature in New York City is proof that these laws are not strictly enforced.

It is evident from the following quotations from the bench that the courts hold no brief for astrology:

> Fortune tellers have always been classed with rogues and mountebanks and generally disreputable members of society to be summarily dealt with for the good of the community. (N. Y. *v.* Ashley 184 App. Div. 522; see also 4 Black. Com. 62.)
>
> That as the statute contains no exceptions as to the method employed by defendants, any prediction of future events for hire is prohibited. (People *v.* Malcolm 90 Misc. Rep. 517.)



Chap. xvi. *A Confutation of Astrology.* 63

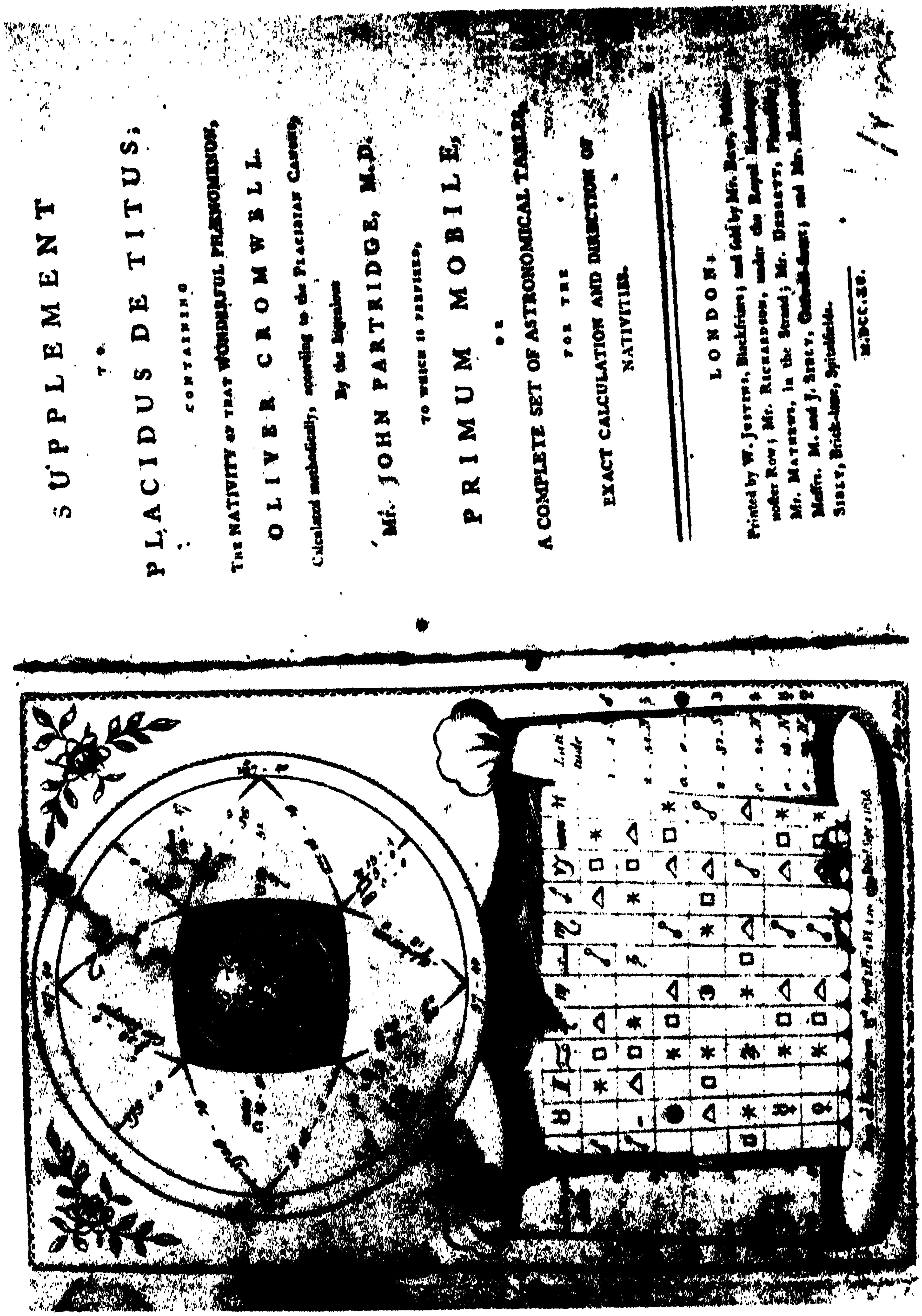
ture fierce. Now, to omit the groundless and arbitrarious division of the *Zodiack* into these four *Trigons*, of which there is only this one hint, that I can imagine, namely, the fitness of *Leo* for one part of the *Fiery Trigon*, the *Sun* being most hot in that Sign; (from which little inlet all the four Elements flew up into Heaven, and took their places in their respective *Triplicities* in the *Zodiack*, with great nimbleness and agility, playing at leap Frog and skipping over one anothers backs in such sort, that dividing themselves into three equal parts, every *Triental* of an Element found it self a Fellow-member of a *Trine* Aspect:) The best jest of all is, that there is no such *Zodiack* in Heaven, or, if you will, no Heaven for such a *Zodiack*, as these *Artists* attribute their *Triplicities* to. For this Heaven, and this *Zodiack* we speak of is only an old error of *Ptolemie*'s and his followers, who not understanding the true *Systeme* of the World, and the motion of the Earth, in which is solv'd the *Anticipation* of the *Æquinoxes*, have phansied a Heaven above the *Cœlum Stellatum*, and a *Zodiack* that did not recede from West to East as the Starry Zodiack does. And this figment which later Ages have laughed off of the Stage, is the only subject of their conceited *Trigons* and *Triplicities*, which therefore are justly laughed off of the Stage with it. Which discovery is a demonstration that the whole *Art* of Astrology is but upon frivolous and mere Imaginary Principles, as we shall further make manifest. And therefore *Physicians* proclaim themselves either Cheats or Fools, that would recommend their skill from such vain elaborations.

15. Fourthly, Now for the *Essential Dignities* of the Planets, this is nothing but the increase of their

K 2 innate

A CONFUTATION OF ASTROLOGY

HENRY MORE, LONDON, 1681, P. 63. THE WRITER, A PHYSICIAN, WAS ONE OF THE "CAMBRIDGE PLATONISTS" WHO ATTEMPTED TO FURNISH A PHILOSOPHICAL BACKGROUND FOR THE NEW SCIENCE OF THE 17TH CENTURY.



SUPPLEMENT

TO

PLACIDUS DE TITUS;

CONTAINING

THE NATIVITY OF THAT WONDERFUL PHÆNOMENON,

OLIVER CROMWELL.

Calculated methodically, according to the PLACIDIAN CANONS,

By the Ingenious

Mr. JOHN PARTRIDGE, M.D.

TO WHICH IS PREFIXED,

PRIMUM MOBILE,

OR

A COMPLETE SET OF ASTRONOMICAL TABLES,

FOR THE

EXACT CALCULATION AND DIRECTION OF

NATIVITIES.

LONDON:

Printed by W. JUSTINS, Blackfriars; and sold by Mrs. BOND, ... under the Royal Exchange; Mr. RICHARDSON, ... Row; Mr. MATHEWS, in the Strand; Mr. DEBRETT, Piccadilly; Messrs. M. and J. SIBLY, ... and Mrs. ... SIBLY, Brick-lane, Spitalfields.

M.DCC.XC.

FRONTISPIECE OF BOOK BY JOHN PARTRIDGE, LONDON, 1790.

THE AUTHOR IS THE ASTROLOGER UPON WHOM JONATHON SWIFT PLAYED THE FAMOUS JOKE.

"Advertising to tell fortunes by any means is prohibited in some states." (Ruling Case Law, Perm. Suppl. p. 2254.) In addition, the "Printers' Ink Statute" makes false advertising a misdemeanor. The model statute provides that any person, firm or association that places before the public an advertisement of any sort, with intention to sell or in any wise dispose of merchandise, securities, services or anything so offered to the public, which advertisement contains any assertion, representation or statement of fact which is untrue, deceptive or misleading, shall be guilty of a misdemeanor. A study of Postal Fraud Orders shows that astrologers continually make use of the printed word in a manner that is deceptive and misleading in order to increase the consumption of their wares, a practice which this statute was designed to prevent. The Printers' Ink Statute has been "enacted into law in twenty-five states, while thirteen additional states have adopted it with modifications." (Boston Better Business Bureau, Fact Booklet, 1938.)

Astrology is condemned by the courts, and the public can find protection against its practices through existing laws. These laws can and should be enforced, and the enactment of more effective and uniform laws should be urged.

V. The Attitudes of Scientists

Why is it that physical scientists are, apparently without exception, opposed to the teachings of astrology? Studies of the stars and planets have shown above all that the amounts of radiation from these bodies that are received on the earth are exceedingly small and that their gravitational effects are so slight as to be negligible in comparison with those from nearby objects.

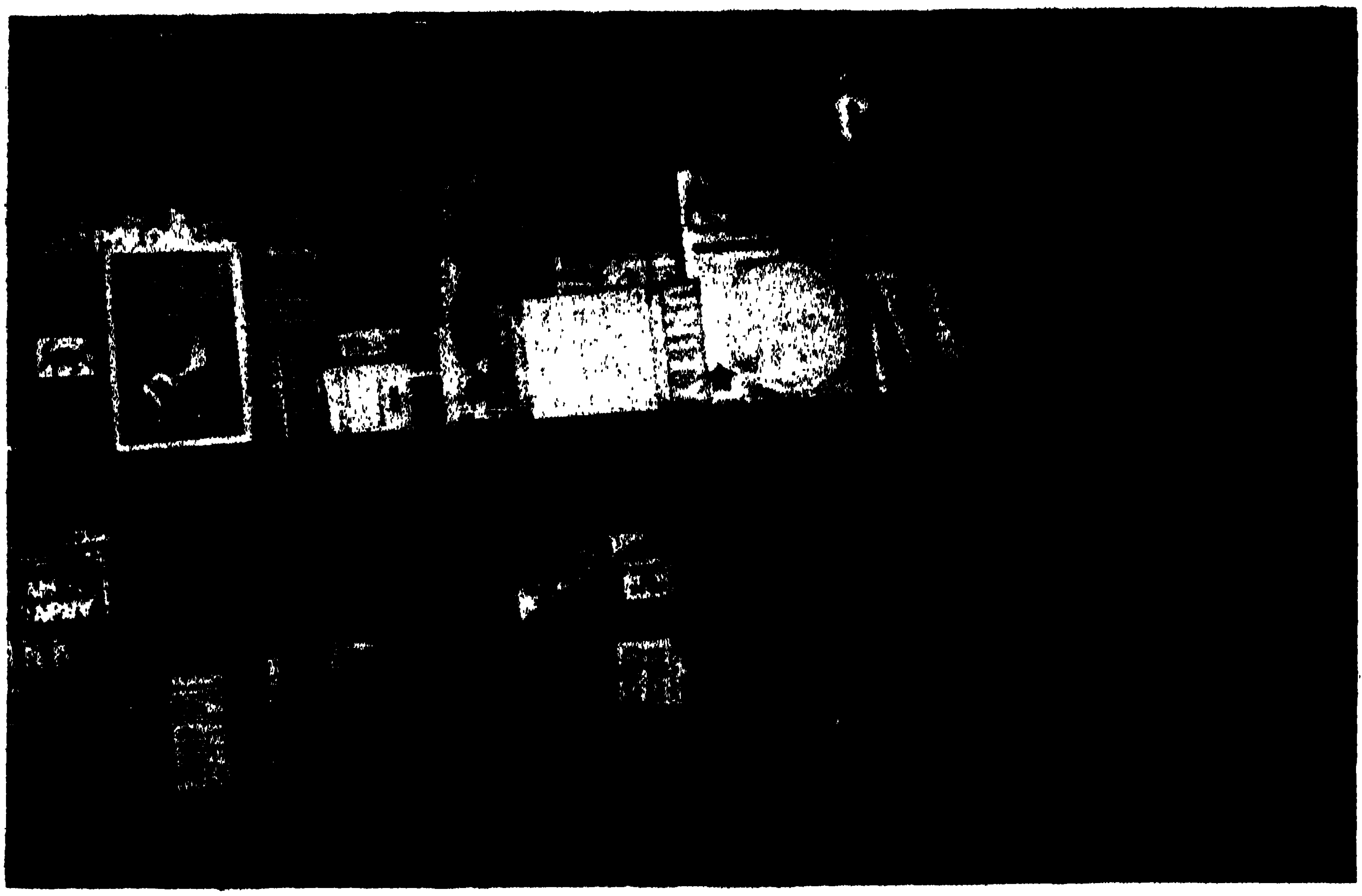
Apart from the sun, the moon is the only celestial body that regularly produces a force in excess of the gravitational force produced by adjacent objects at the time of birth. Only under the most favorable conditions can the gravitational attraction of the planet Mars equal that produced by the doctor in charge of the delivery.

The apparent brightness of a star or planet will hardly be more than that of the tail-light of an airplane passing in flight overhead. The walls of hospitals and other buildings where babies are born are opaque to all known radiations from the planets.

Is it possible that there exists some as yet unknown way in which the planets can exert their influence on human affairs? Every one realizes that there are many problems, for example, those presented by hypnotism and thought transfer, that have not yet been explained in a satisfactory fashion. The case of astrology falls outside this class. It is extremely unlikely that the planets, which have a considerable degree of similarity in their general constitution, would affect human affairs according to the generally accepted scheme of astrology. For astrology as it is practiced to-day not only requires an unknown mechanism for the transfer of planetary influence, but it requires further that planets with a considerable degree of similarity should affect human affairs in an entirely dissimilar fashion.

Astrologers attach great influence to the signs of the zodiac. Because of precession of the equinoxes the apparent positions of these signs have shifted by more than twenty-five degrees during the past twenty centuries. It is impossible to understand how the stars can affect human affairs, but it is doubly difficult to suggest a mechanism to account for the influence of the zodiacal signs, which continue to change their position among the stars.

The choice of the moment of birth as the one and only critical instant seems



TEN PERIODICALS ON ASTROLOGY

ARE REGULARLY CARRIED BY THIS MAGAZINE STORE IN HARVARD SQUARE WHERE, ON THEIR WAY TO CLASSES, HARVARD STUDENTS AND PROFESSORS BUY THEIR READING MATTER. SOME OF THESE ASTROLOGICAL PUBLICATIONS SELL BETTER THAN "THE ATLANTIC MONTHLY" AND "THE HARVARD GUARDIAN." NOTE THAT THE ASTROLOGICAL MAGAZINES ARE MOST PROMINENT IN THIS WINDOW.

arbitrary, and one is inclined to ask why this particular moment should be favored over the time of conception or the first exposure to fresh air?

An interpretation of the rules laid down by astrologers demands the existence of an unimaginable mechanism of action. Astrologers have not provided us with as much as a sound hypothesis that might serve as a basis for their speculations. Astrologers attempt to offset this lack of a sound working hypothesis by the introduction of terms and concepts that are unknown to physicists and astronomers. No one, with a high-school training in physics, should be fooled into accepting an explanation of the laws of astrology in which the term "cosmic vibration" figures prominently.

Scientists would feel justified in considering astrology as a legitimate field of scientific inquiry if astrologers could claim that its basic rules had been established through a rigorous study of correlations. But such a study has not been made. The rules by which astrologers interpret their horoscopes have not been derived from any known experiments or observations. Astrologers frequently claim an observational basis in the experience of forgotten generations far back in antiquity, but pure superstition can claim as sound a basis. In the cases of planets discovered in our times (Uranus, Neptune, Pluto) the evidence is conclusive that their influences on men were ascribed by the astrologers before preliminary observational tests of the influences could have been made, and even before accurate orbits could be assigned to the planets.

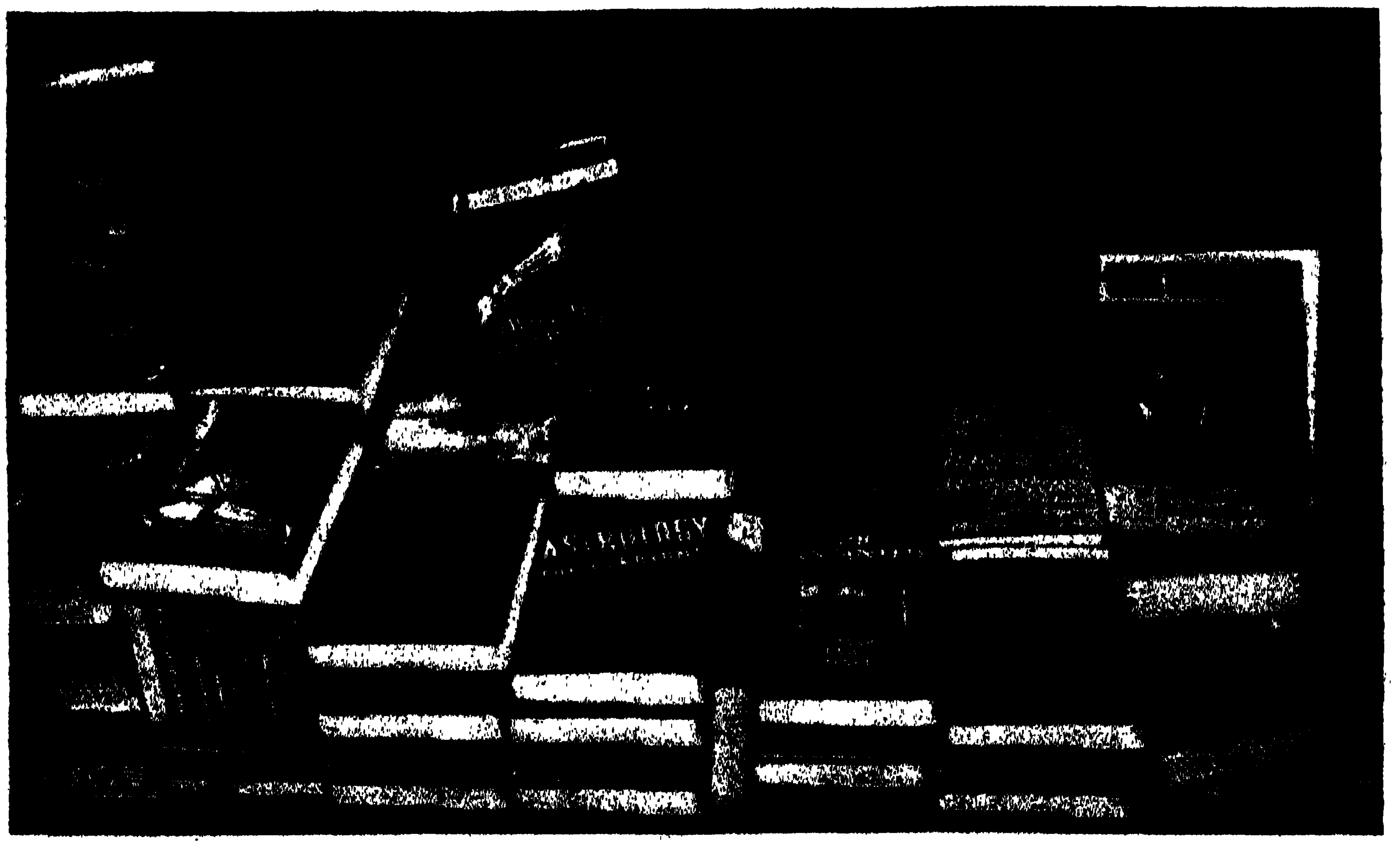
One might conceivably prove or disprove astrology as it is practised to-day

through a study of successes and failures of predictions based on horoscopes. Such a study would necessarily be of a statistical nature and the results should be subjected to rigorous statistical analysis. The committee has been unable to find anywhere the source material for a decisive test. Those few tests that have been carried out were based on incomplete data about the exact times of birth or the precepts of statistical analysis were not followed with sufficient care.

It is, however, possible to test for certain broad influences assigned by astrologers to specific planets and signs of the zodiac. Farnsworth has studied the zodiacal birth signs of some two thousand musicians and painters. He found that the correlation predicted by astrology—Libra is supposedly the esthetic sign—was absent. A member of the committee has made some similar tests for birth dates of scientists listed in "American Men of Science." The investigation shows that the frequency distribution of birth dates of scientists resembles very closely a random distribution and that the seasonal variations of birth dates resemble very closely those found by Huntington.

The seasonal variations in birth dates are highly significant for such tests. Huntington has shown that about 15 per cent. more people are born in January–February and September than in May–June and November. These seasonal variations are reflected in the separate frequencies for all professions, engineers, industrialists, clergymen, bankers, physicians, chemists and authors. (See Huntington's "Season of Birth," 1938.) Now if instead of months zodiacal sun-signs are considered, the general trend does not change, whereas for astrological influences we should expect widely different correlations for the different professions.

In conclusion, we find that astrologers



WHERE HARVARD STUDENTS BUY THEIR TEXT BOOKS

THE PHOTOGRAPHER FOUND THIS POPULAR BOOK ON ASTROLOGY PROMINENTLY DISPLAYED BETWEEN "THE LIFE OF PASTEUR" AND "THE ANOINTED." AMONG OTHER BEST SELLERS ON THIS SHELF IS A GREAT STACK OF VOLUMES OF "GONE WITH THE WIND."

have failed to suggest a workable mechanism by which the stars and planets can exert their influence on human destiny. The doctrine of astrology can not claim that it is in any way supported by statistical evidence from observed correlations, and until such correlations are established scientists can not accept the precepts of astrology.

VI. Psychologists State Their Views on Astrology

The committee for the study of astrology has been fortunate in having the cooperation of some leading psychologists. At the request of Professor G. W. Allport, the executive council of the Society for Psychological Study of Social Issues authorized the release by the committee of a statement entitled: "Psychologists State Their Views on Astrology." We are glad to present this statement without change.

Psychologists find no evidence that astrology is of any value whatsoever as an indicator of past, present, or future trends in one's personal life or in one's destiny. Nor is there the slightest ground for believing that social events can be foretold by divinations of the stars. The Society for the Psychological Study of Social Issues therefore deplores the faith of a considerable section of the American public in a magical practice that has no shred of justification in scientific fact.

The principal reason why people turn to astrology and to kindred superstitions is that they lack in their own lives the resources necessary to solve serious personal problems confronting them. Feeling blocked and bewildered they yield to the pleasant suggestion that a golden key is at hand—a simple solution—an ever-present help in time of trouble. This belief is more readily accepted in times of disruption and crisis when the individual's normal safeguards against gullibility are broken down. When moral habits are weakened by depression or war, bewilderment increases, self-reliance is lessened, and belief in the occult increases.

Faith in astrology or in any other occult practice is harmful in so far as it encourages an unwholesome flight from the persistent problems of real life. Although it is human enough to try to escape from the effort involved in hard thinking and to evade taking responsibility for one's own acts, it does no good to turn to magic and mystery in order to escape misery. Other solutions must be found by people who suffer from the frustrations of poverty, from grief at the death of a loved one, or from fear of economic or personal insecurity.

By offering the public the horoscope as a substitute for honest and sustained thinking, astrologers have been guilty of playing upon the human tendency to take easy rather than difficult paths. Astrologers have done this in spite of the fact that science has denied their claims and in spite of laws in some states forbidding the prophecies of astrology as fraudulent. It is against public interests for astrologers to spread their counsels of flight from reality.

It is unfortunate that in the minds of many people astrology is confused with true science. The result of this confusion is to prevent these people from developing truly scientific habits of thought that would help them understand the natural, social, and psychological factors that are actually influencing their destinies. It is, of course, true that science itself is a long way from a final solution to the social and psychological problems that perplex mankind; but its accomplishments to date clearly indicate that men's destinies are shaped by their own actions in this world. The heavenly bodies may safely be left out of account. Our fates rest not in our stars but in ourselves.

THE FUTURE OF FORESTRY AND GRAZING IN THE SOUTHERN PINE BELT[1]

By ELWOOD I. TERRY

PROFESSOR OF GEOGRAPHY AND CONSERVATION, WINTHROP COLLEGE, SOUTH CAROLINA

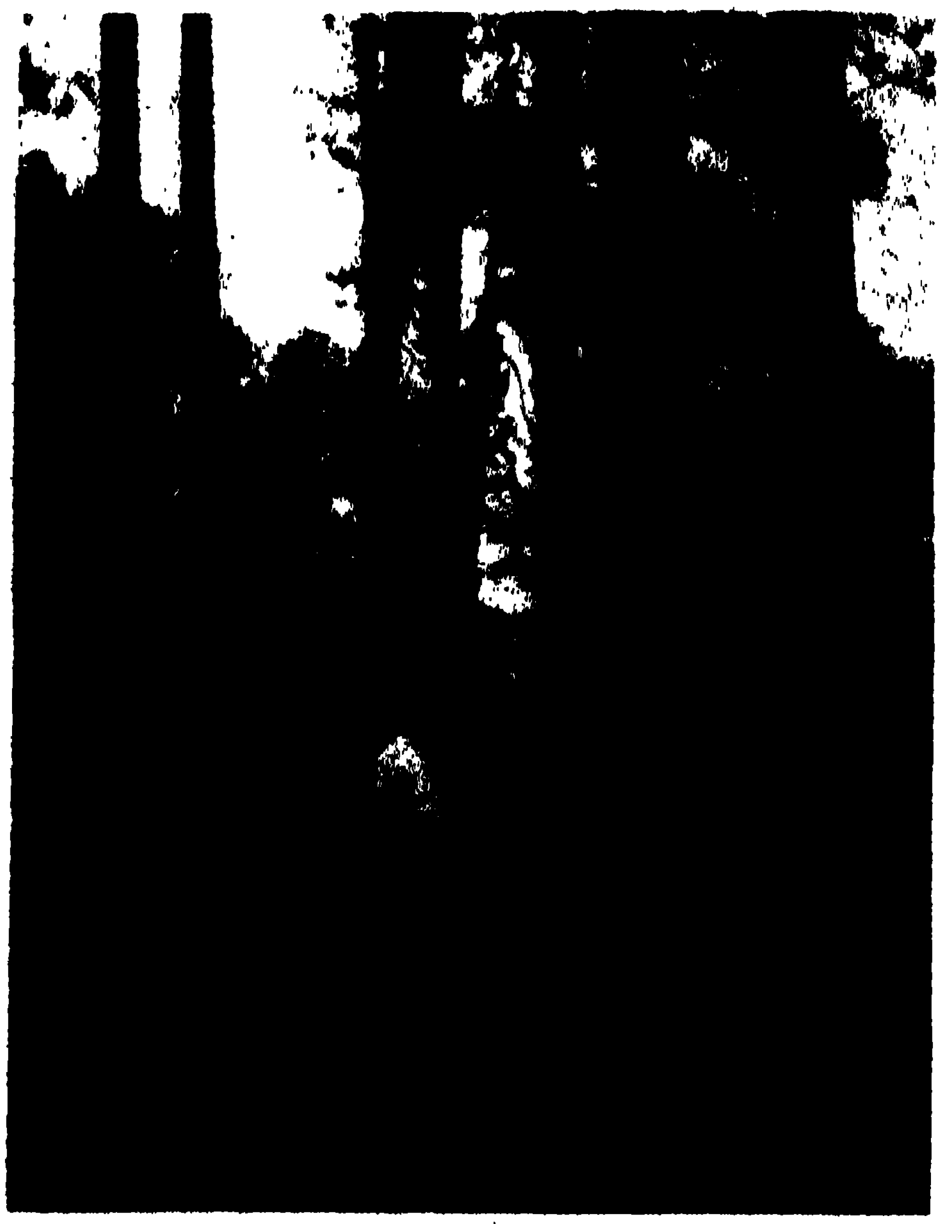
THE practice of setting out fire "to improve the grazing" is responsible for most of the woods-burning in the South. Many other causes are often cited, but they are almost inconsequential when compared to the time-honored custom of "burning off the rough." And there are among intelligent live-stock men some warm defenders of that practice. A few years ago an article appeared in a forestry magazine entitled "The Forest that Fire Made" (meaning the Southern longleaf-pine forest), which had nearly the effect of a bombshell exploding in the forestry camp.[2] It was written by S. W. Greene, of the Bureau of Animal Industry, who for a number of years had been connected with the Coastal Plains Experiment Station in Mississippi, studying the effect of ground fires upon forage production in the South.

The point of Mr. Greene's argument was that the great forest of nearly pure longleaf pine which the white man found when he landed upon these shores was the result of repeated ground fires that the Indians were in the practice of setting to clear off the underbrush and make easier the hunting of the deer. This favored the longleaf pine over competing species because of its remarkable resistance to fire in early youth. It survived the light ground fires that killed

[1] Photographs, courtesy of U. S. Forest Service, Southern Region.

[2] S. W. Greene, *American Forests*, October, 1931.

A PULP AND PAPER MILL IN SOUTH GEORGIA



A VIRGINIA LONGLEAF PINE
STAND BADLY FIRE DAMAGED.

the seedlings of shortleaf and loblolly pine and burned back the hardwood "brush." So when De Soto and his men came in 1539 they found an open-growth forest of almost pure longleaf pine stretching from the Atlantic to the Mississippi and beyond, devoid of underbrush and affording an easy highway for them to travel over and drive along their herds of cattle and swine.

Now forest ecologists have always attributed the typical longleaf-pine stands of the Atlantic and Gulf coastal plains to the deep sandy soil on which they invariably grew. The longleaf pine is one of the few trees—and the only important timber tree—that can thrive and grow to large size on such dry sandy sites because of the remarkably long taproot that it develops, often penetrating the soil for fifteen or twenty feet in search of permanent moisture. No other tree of the eastern United States naturally develops such an enormous taproot. Along the rivers which cross the coastal plain, on the moister and richer overflow bottomlands, we find a mixed forest of dense hardwoods and cypress, from which the pine is rigidly excluded. The extensive stretches of deep sandy soil covering the slightly more elevated interfluves are undoubtedly the fundamental natural factor in determining the longleaf type of forest—the "pine barrens" of the pioneers. But the writer agrees with Mr. Greene in believing that the generations or perhaps centuries of ground burning to which the "piney woods" have been subjected have profoundly modified their aspect. Only, while from the viewpoint of the grazing man the change has been for the better, from that of the lumberman it has been for the worse. In his article Greene plainly states: "Without annual grass fires the grasses are smothered out and neither cattle nor quail can long exist in such a forest." And with that statement no one who is thoroughly familiar with the Southern pine forest will care to enter into a controversy. It is as true of the shortleaf and loblolly pine forests as of longleaf.

It should be recognized, however, that Mr. Greene looks at these forests with the apperception of the grazing man. He thinks that fire is responsible for the origin of this type of forest, but his direct interest is not in the timber-producing values of these forests but in their value for grazing. To him the ideal forest is one free from underbrush but carpeted with a heavy growth of grass and so open that a deer may be seen through the timber "as far as the eye can reach." That undoubtedly makes an ideal wooded pasture, but to the lumberman or forester appraising its timber values it is comparable to a ten-acre field of corn in which the mature stalks are so few and far between that a man standing on one side of the field could see a horse trotting along a road on the opposite side.

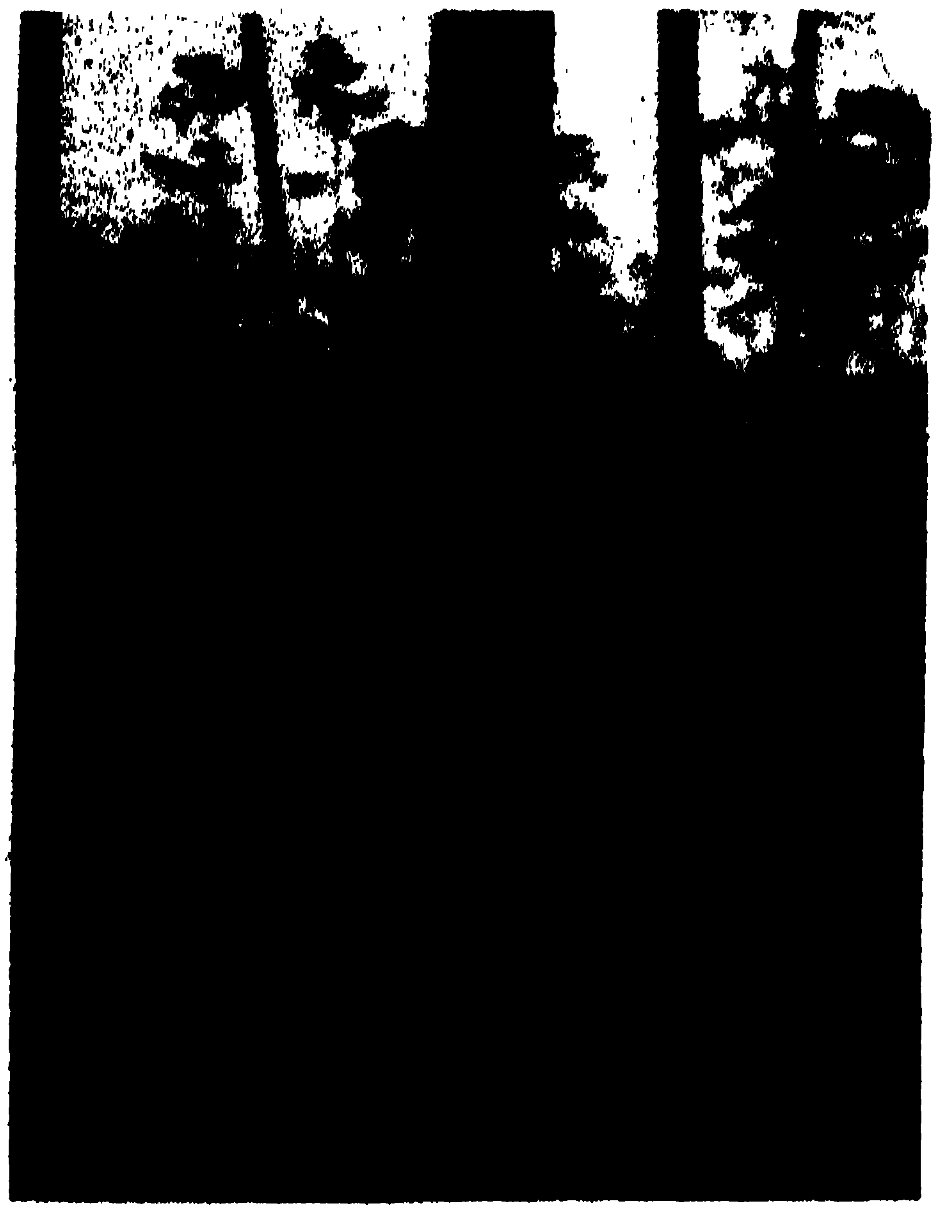
But we must concede that the early pioneers, in burning off the leaf-litter

and ground cover, did attain their object. They increased the amount of grass for their stock to feed on. For it is unlikely that much if any grass ever grew beneath the dense canopy of the virgin forest anywhere in the humid eastern part of our country, not even excepting the sandiest soils of the pine barrens. But after the leaf-litter, herbaceous plants and seedling trees have been burned off grass will usually come in, even under fairly thick shade. And if burning is continued year after year, destroying and preventing reproduction, the forest will become more and more open and the grass will grow rank and form a sod, for grass loves the sunlight. In time nothing will be left of the forest but an open grove of overmature, decadent trees, and they will finally disappear.

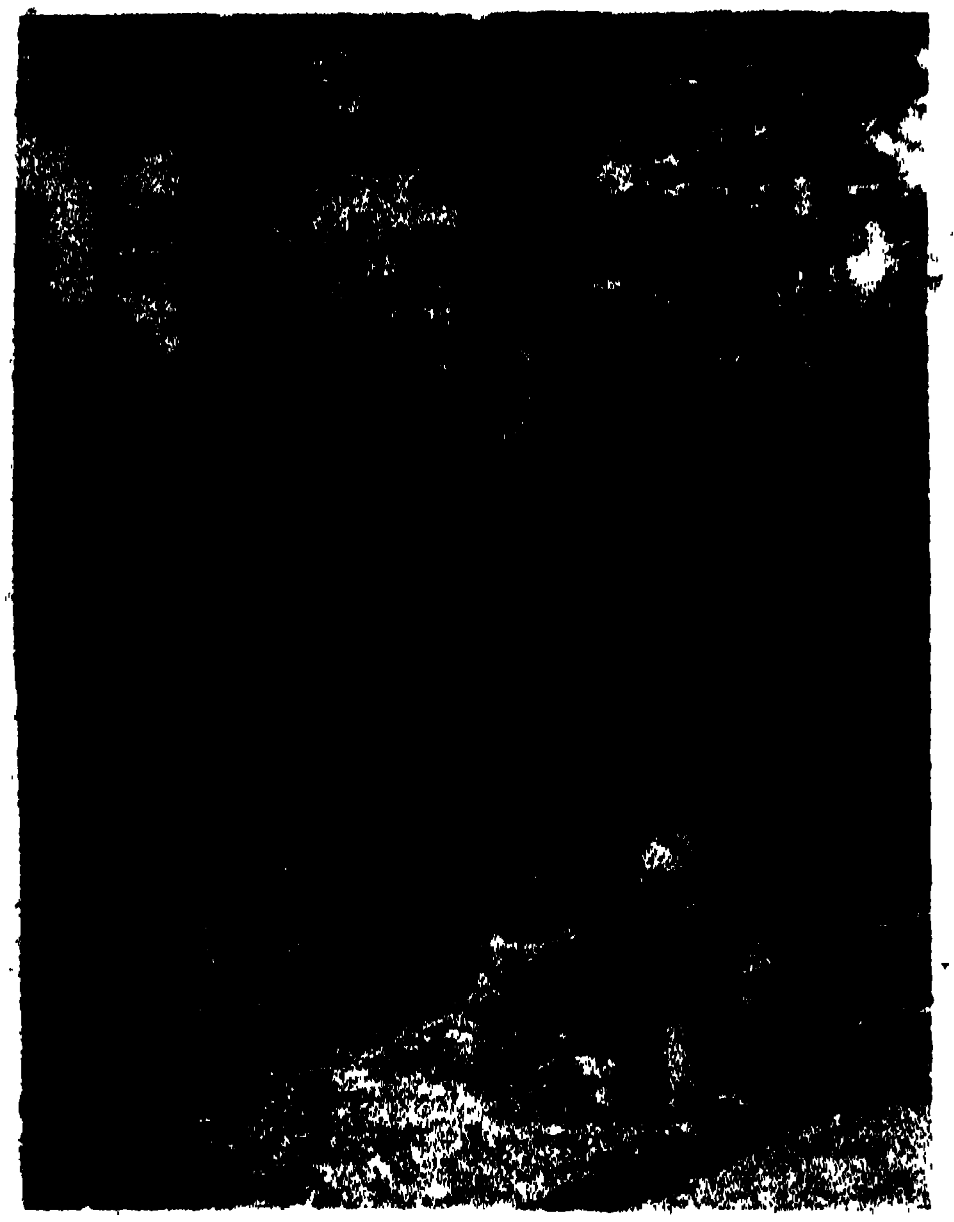
That is the probable history of the considerable area of "savannas" or open grass lands that the early explorers found frequently intercepting the forest in our Southern states. It was likewise the cause of the low density or open character of the longleaf-pine forest that De Soto rambled over. For as Mr. Greene points out, there is positive historical evidence that the Indians had made a practice of burning over the forest frequently for hunting purposes long before the Europeans appeared. A forest long subjected to recurrent ground fires undergoes profound alteration from its original condition and can not truly be called a virgin forest. If that be the historical fact, then it may be asserted that in all probability no white man has ever beheld the longleaf-pine forest in its primeval state, and has no objective example of what such a forest may be like or the quantity of timber it may produce. Neither does it give any index of the yields of forest products that may be obtained under good forest management, with fire and grazing precluded. But, in this warm humid region with great natural capacity for tree growth, the long-continued ground-burning is undoubtedly responsible for the open nature of the forest with its slow rate of growth and pitiably small yield of timber, seldom exceeding four or five thousand board feet per acre. And most of the trees composing those stands are two hundred years or more old. In the Pacific Northwest old-growth Douglas fir often averages a hundred thousand board feet per acre over extensive areas, and the virgin forests of the Northeast and the Lake States gave far heavier yields than the Southern pine.

But nearly all the Southern pine forest has been cut over at least once, and fully three fourths of the area that is now in some stage of forest growth is covered with second-growth timber, which has repossessed the land following the removal of the original stand. From now on we must depend upon "second growth" if the forest industries are to be perpetuated. But at what rate are

13-YEAR OLD LONGLEAF PINE REPRODUCTION ON THE CHOCTAWHATCHEE NATIONAL FOREST, FLORIDA.



TURPENTINED LONGLEAF PINE
BADLY FIRE DAMAGED. NOTE OPENNESS OF STAND AND ABSENCE OF YOUNG GROWTH. WESTERN FLORIDA.



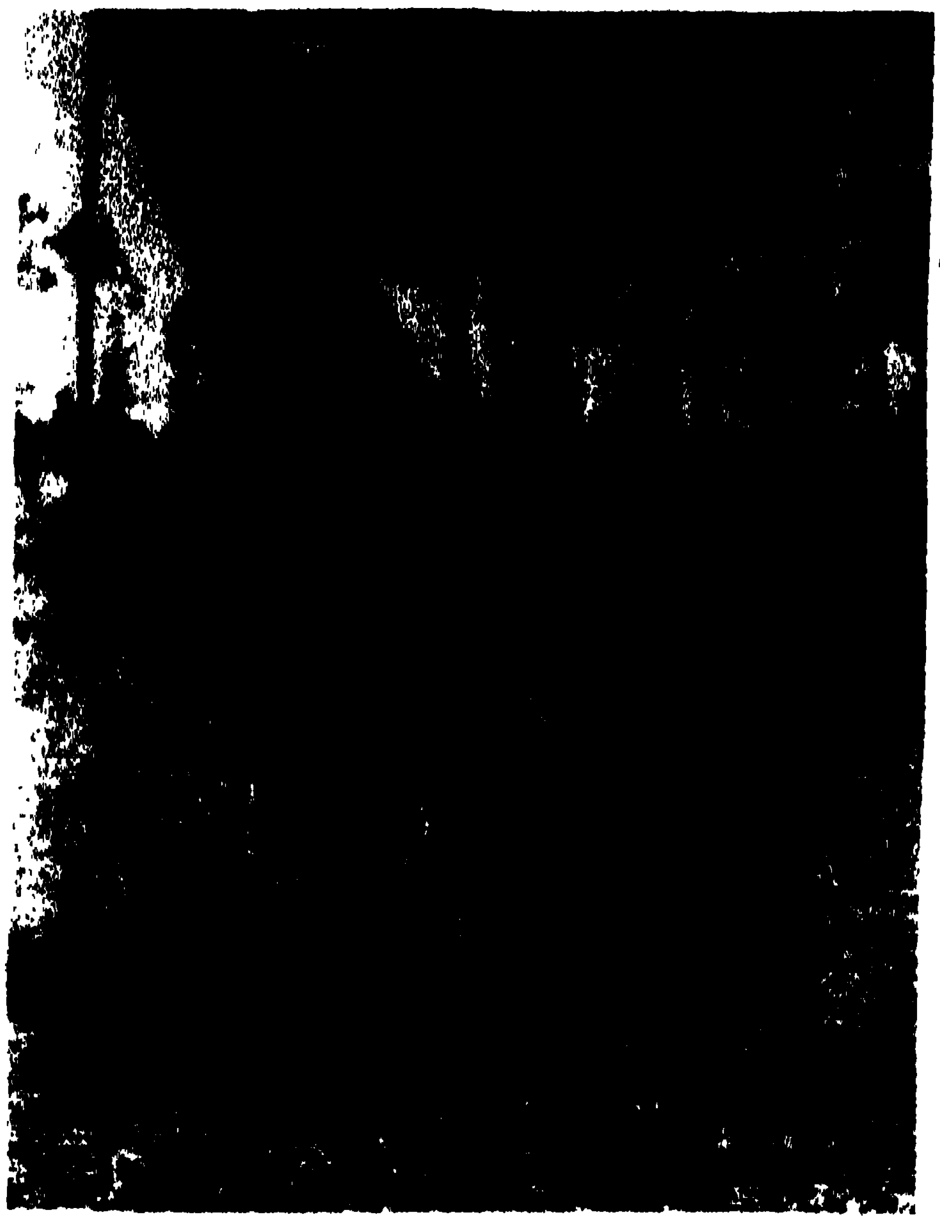
SELECTIVE CUTTING
IN OLD GROWTH YELLOW PINE IN SOUTH CAROLINA. THIS TREE IS ECONOMICALLY MATURE AND ITS REMOVAL WILL PERMIT INCREASED GROWTH IN THE SMALLER TREES.

these second-growth forests, which have been subjected to ground fires and grazing, reproducing a timber supply?

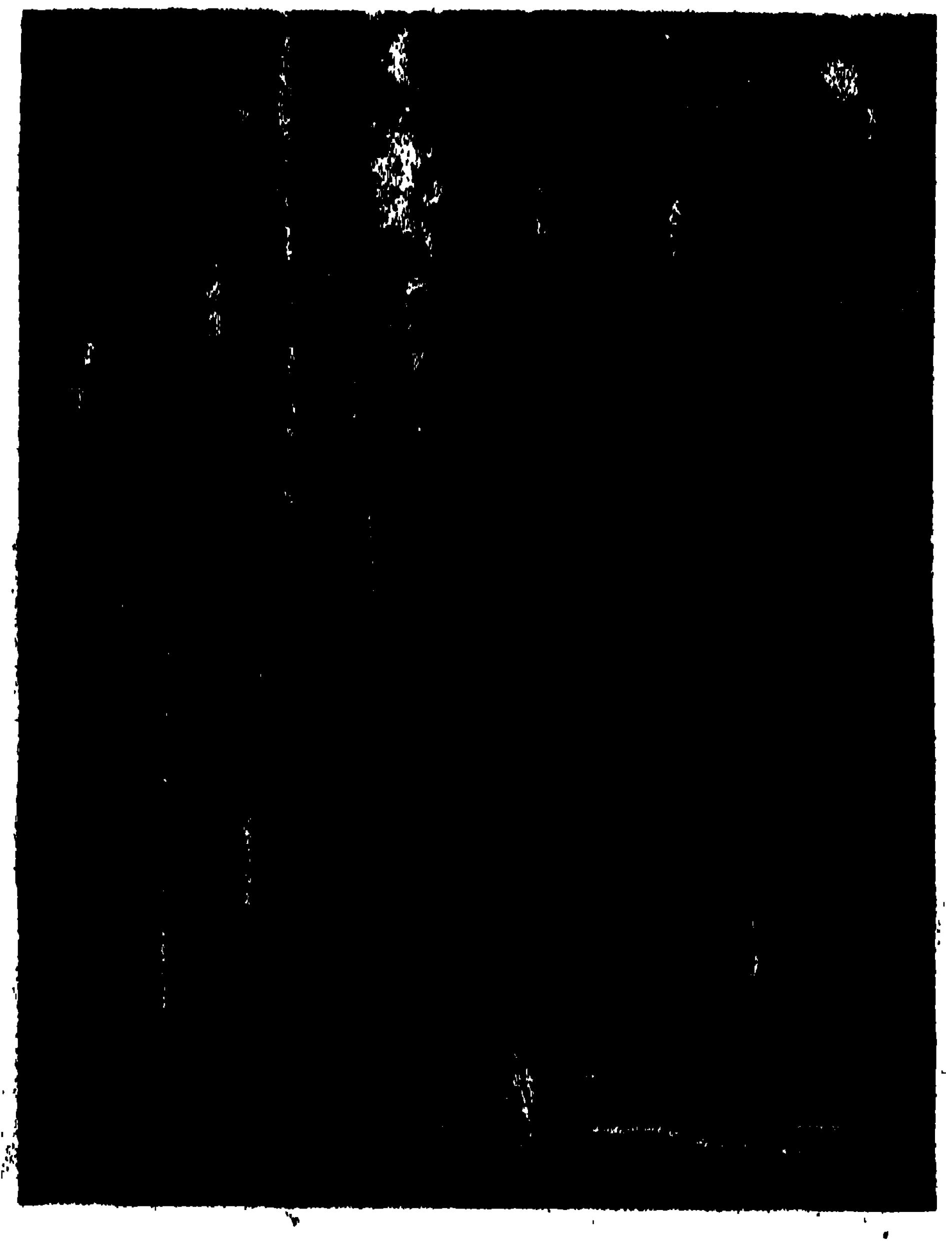
The Forest Service has just completed its forest survey, or stock-taking, of the timber resources of the lower South, and finds that over most of the longleaf-pine belt the average stand per acre is about 1,500 board feet of saw-timber and 2.7 cords of wood in trees of less than saw-timber size. If the whole stand were cut for pulpwood it would make only 6 or 7 cords per acre. That is a miserably low yield, and it would not pay to grow such stands under forest management. Compare it with yields of second-growth white pine in the Northeast, where stands fifty to sixty years old often yield 50,000 board feet to the acre, or with the "cultured" spruce forests of central Europe, where yields of 140,000 board feet per acre are regularly obtained, and that on soils which are naturally no more fertile than those of our Southern pine lands. Such high yields may never be produced by longleaf pine even under the most favorable conditions, but yield tables for our Southern pines recently compiled by the Forest Service show that fully stocked stands of longleaf may be expected to yield 45,000 board feet of timber per acre in an eighty-year rotation, or forty cords of peeled pulpwood per acre in forty years, and fifteen cords in twenty years. Shortleaf, loblolly and slash pines all produce considerably higher yields. These four Southern pines are all valuable timber species and as a group rank among the most rapidly growing timber trees of the United States. Longleaf and slash pine, yielding crops of both turpentine and timber, are the famous "dual-purpose trees." All four species can be used for making the kind of paper pulp from which "kraft" paper is manufactured. That is the brown paper used for wrapping packages and for paper bags, and the same pulp is also used for making cardboard, the fiber-board cartons and many

other articles. The South has already captured the kraft-paper industry. More than forty mills are now in operation in this region, making either the pulp only or both the pulp and finished paper products. Between Virginia and Texas at least sixteen new mills have been built during the past two years. For 1938 the consumption of pulpwood was estimated to be between six and seven million cords.

The lumbermen throughout the South are panic-stricken over the rivalry they are encountering from the pulp mills for raw material. And now that the experiments of the late Dr. Charles Herty indicate that a good grade of newsprint can be made at low cost from Southern pine, the prospects are excellent for a general migration of the newsprint-paper industry to the Southern states within the next decade or so. That will surely eventuate if the paper manufacturers can be assured of a permanent supply of pulpwood for their mills. But can they? What will be the drain on the Southern pine forest when the newsprint mills compete with the kraft mills for raw material? The production of newsprint paper far exceeds that of kraft. The capital required to build and equip a paper mill runs from seven to ten million dollars or more, and it does not pay to invest that amount unless a long life can be assured to the enterprise. Dr. Herty has been quoted as saying that a tract of 45,000 acres will supply enough wood perpetually for a mill of 150 tons daily capacity. (Many of the new kraft mills have a daily capacity of 300 tons.) But that could only be done on a tract that was organized and systematically developed for continuous production under intensive forest management. It would not pay to reproduce such stands as composed the bulk of the pine barrens even before the lumbermen cut them over, nor would such stands maintain a paper industry for any great length of time.



WINDTHROWN LONGLEAF PINE TREE
DUE TO BOXING FOR TURPENTINE FOLLOWED BY FIRE. WESTERN FLORIDA.

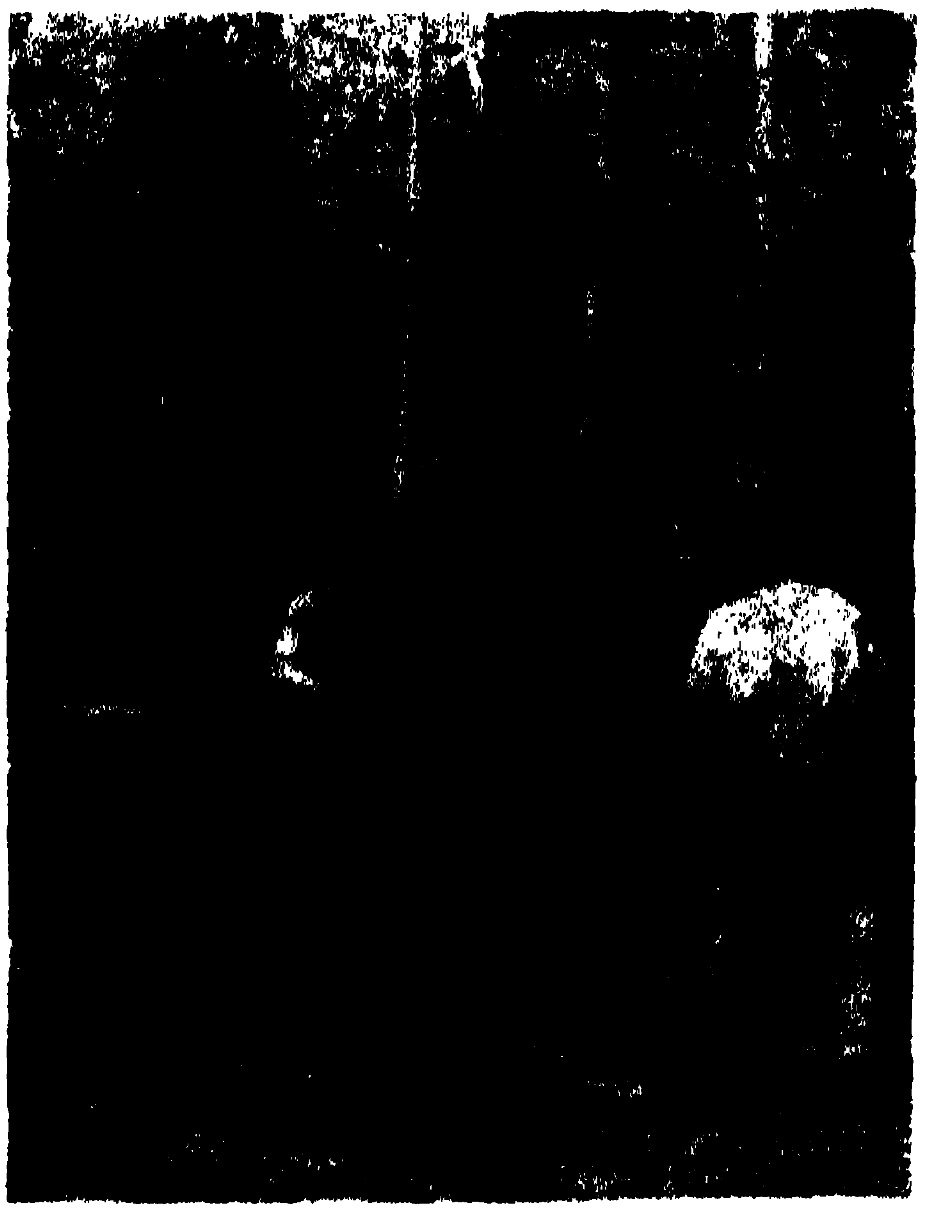


YELLOW PINE REPRODUCTION
THIRTY YEARS OLD. ON AN ABANDONED OLD FIELD NEAR MILTON, FLORIDA. SOME DAMAGE FROM EARLIER FIRES. STAND TOO DENSE AND IN NEED OF THINNING.

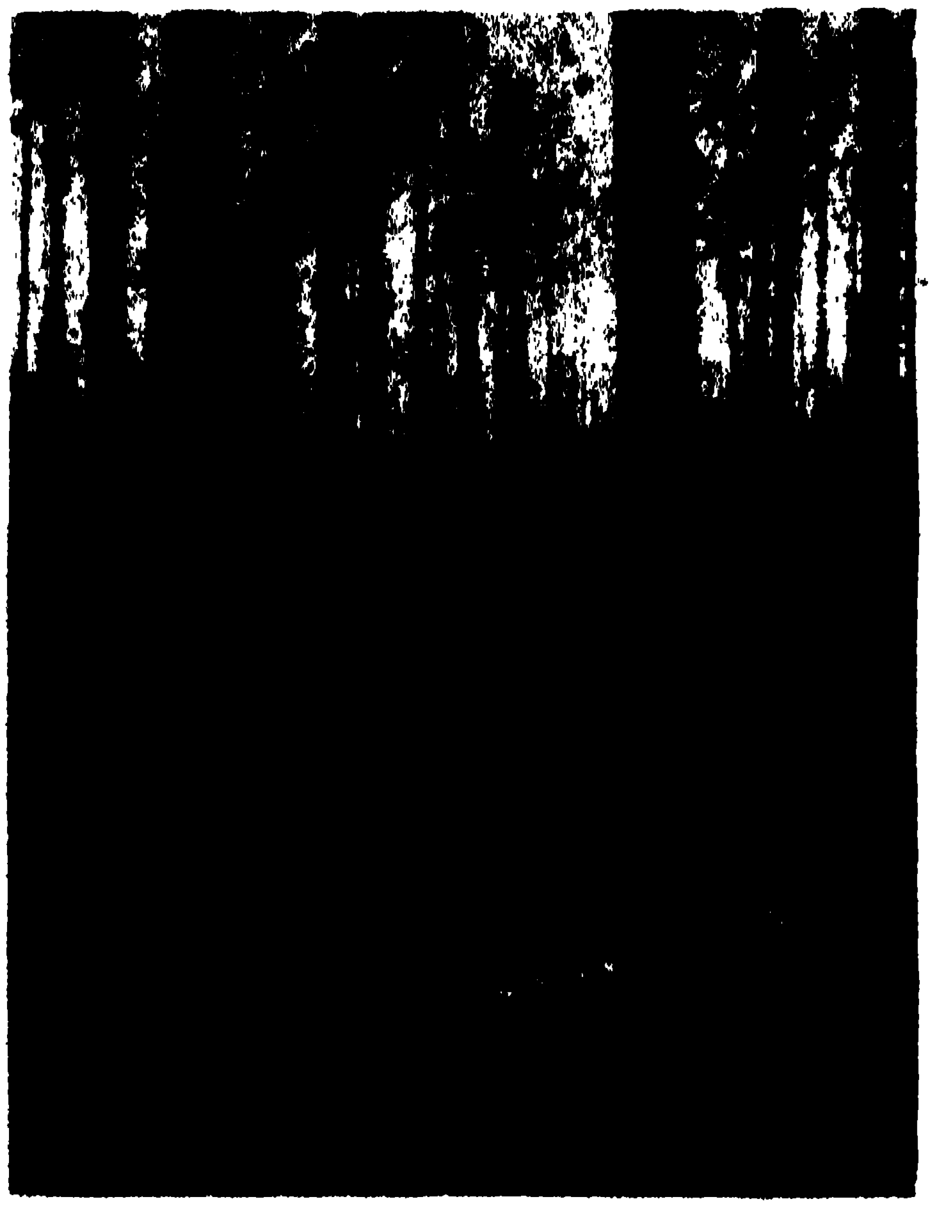
But to revert to the grazing business, which has always been important in the South and has good prospects of becoming more important in the future if properly developed. The opening paragraphs of this article suggested the age-long conflict between the stockman and the forester, a conflict that was being waged in the Old World for centuries before America was discovered. The cool, moist climate of Scotland indicates that it would naturally be a forested country, and the Scottish highlands were originally covered with dense forests. But through centuries of sheep-grazing the forests were gradually destroyed and for several hundred years those hills have been covered with grass and heather. Sheep are more destructive to the forest than cattle, but continual burning and grazing will bring our Southern pine forests to a similar fate. The longleaf-pine forest is not so much the forest that fire made as it is the forest that fire made *poor,* and is making poorer from decade to decade when considered as timber-producing property. The director of the recent forest survey states in his report: "An examination of the second-growth forests throughout the belt in both pine and hardwoods shows that much of the area is less than half stocked. Besides being poorly stocked, many of our young forests are filled with cull trees, trees of stunted growth, and trees that are of poor quality and low value for industrial use. . . . The greatest proportion of clear-cut and non-restocked area is found in the naval-stores belt where, in some localities, the long-continued practice of systematic woods-burning has prevented the re-stocking of cut-over land or brought about a worthless cover of scrub oak."

The European forester hates to see

THE RESULT OF PROTECTION AGAINST FIRES IN SOUTH GEORGIA
TO THE LEFT OF THE FIRE LINE, A DENSE POLE STAND OF SLASH PINE. TO THE RIGHT, FREQUENTLY BURNED-OVER, SPARSE, STUNTED PINE SAPLINGS AND TANGLES OF SEDGE GRASS.



BUCKING A TREE UP INTO SAWLOGS
THESE LARGE TREES YIELD CLEAR LOGS AND HIGH-GRADE LUMBER.



A FINE STAND OF LONGLEAF PINE
ENTIRELY KILLED BY ONE BAD FIRE. NORTHEASTERN FLORIDA.

grass on his forest floor as much as a market gardener hates to see weeds in his onion beds. Grass robs the soil of both food and moisture that the trees need for making their best growth, and seriously retards or often prevents reproduction. Because of years of such mistreatment our Southern woodlands are yielding only a small fraction of the timber they are capable of producing if well protected and properly managed. Neither is the use of fire necessary in order to regenerate the forest to pine. The forester knows how to reproduce stands of pure pine or any other desirable species without resorting to fire.

But, on the other hand, the foresters should concede that in trying to convince the stockmen of the evils of woods burning they started off on the wrong track. It is bad for the trees but good for the grass. Since writing his article on the forest that fire made, Mr. Greene has released from time to time further statements[3] concerning the results of his researches, which may be briefly summarized as follows: Cattle gained 45 per cent. more when grazed on areas that had been burned than on unburned areas. The growth of grass was more

[3] The latest publication bearing on this subject is Technical Bulletin No. 683 of the U. S. Department of Agriculture, published in June, 1939, entitled "Effects of Fire and Cattle Grazing on Longleaf Pine Lands as Studied at McNeill, Mississippi," by W. G. Wahlenberg, of the Forest Service, S. W. Greene, of the Bureau of Animal Industry, and H. R. Reed, of the Bureau of Plant Industry. This is a 52-page bulletin describing in detail the experiment that was conducted at the Mississippi Agricultural Experiment Station for ten years, from 1923 to 1933, on four sample areas representing, respectively, burned pasture, unburned pasture, burned ungrazed and unburned ungrazed land. The results of this elaborate investigation may be briefly summarized in the statement that annual burning improves the grazing but is detrimental to the regeneration of the pine. Which simply corroborates the consensus of opinion long held by intelligent observers throughout the Southern pine region.

OPEN GROWTH TURPENTINE ORCHARD IN LONGLEAF PINE VIRGIN FOREST ON CHOCTAWHATCHEE NATIONAL FOREST, FLORIDA. FIRST YEAR OF CUPPING. NOTE LOW POSITION OF CUPS AND NARROW STREAKS.

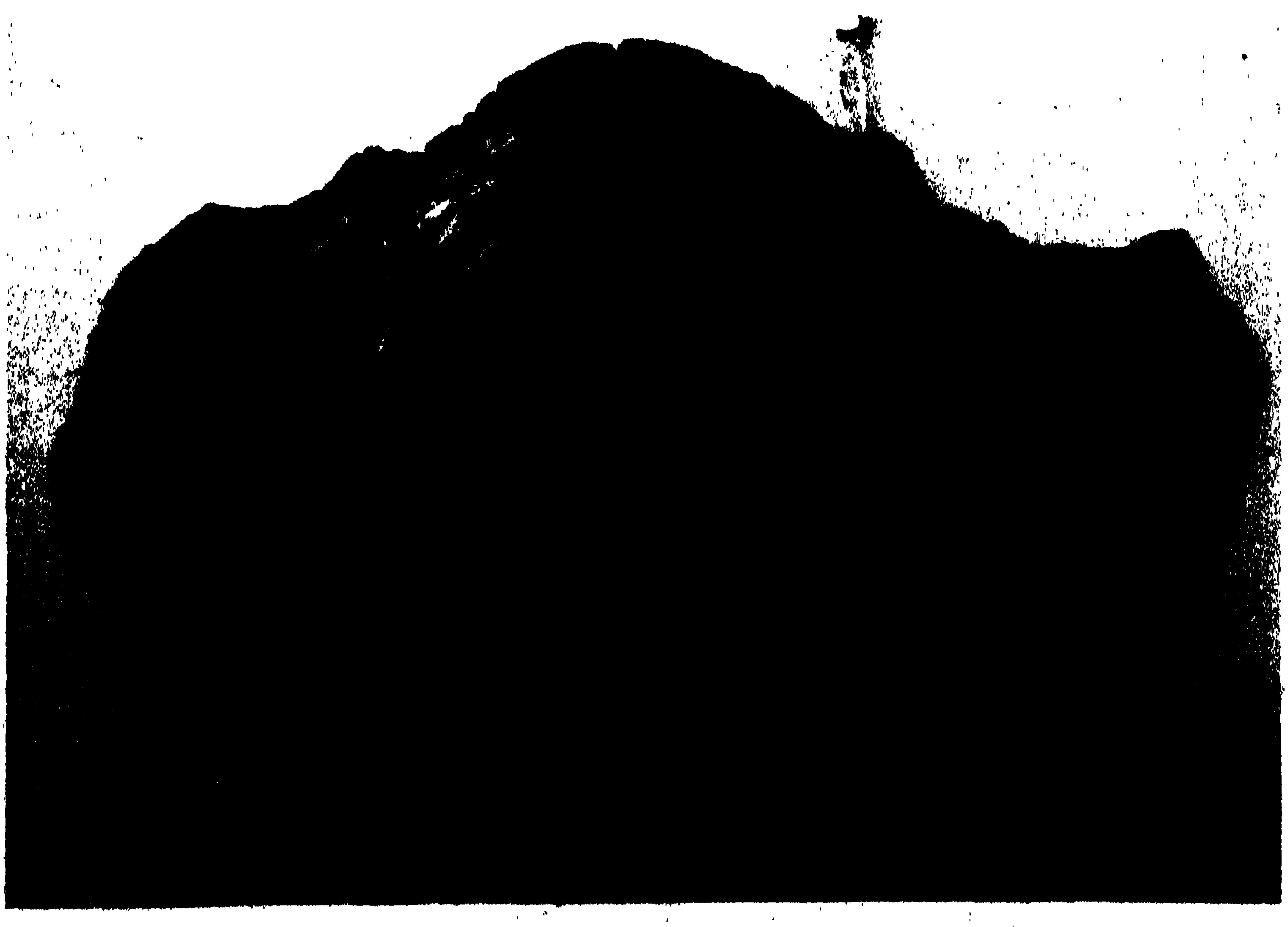
than twice as heavy on the burned than on the unburned area, and there were nearly three times as many legume plants on the burned area. Analysis of the forage also showed that the grasses from the burned areas were much higher in feeding values.

When the foresters came South and appraised, as they did very quickly, the enormous damage to growing timber that was done by woods-burning, they tried to convert the stockmen from that practice by preaching to them that these ground fires were detrimental to the grazing as well as to the timber. They never met with much success in converting the men whose interests were solely in cattle, and now the practice of the live-stock men is confirmed by expert authority. It is a necessary practice in a humid region with naturally dense forest growth if live stock are to be grazed in the woods. The forest must simply be converted into wooded pasture land. With landowners, however, who were more interested in raising timber than cattle, whether for naval stores, saw-timber or pulpwood, the foresters were more successful, and only a few years of protection were enough to convince these people that fire-suppression on their lands was a good thing for them.

Woodlands make poor pastures, and the grazing of woodlands will result in poor crops of timber. Even if not subjected to annual burning a heavily grazed tract of timber will rapidly deteriorate. Pasturing and timber production can not be practised on the same land except to their mutual disadvantage. The conclusion is evident. The production of timber for commercial purposes and the raising of live stock should be conducted on separate areas. In many parts of the South that goal can not be reached in a year or a decade, but

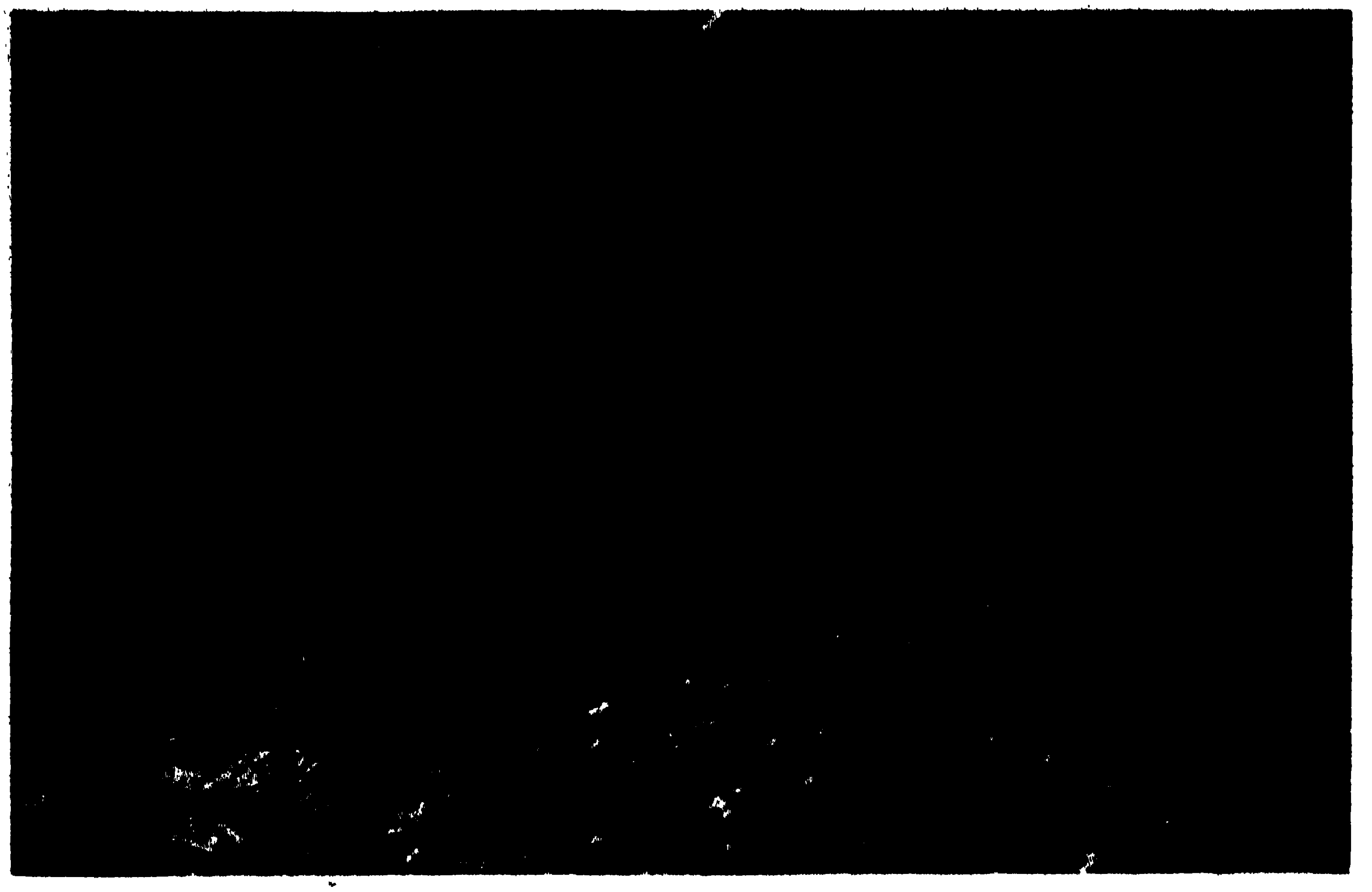
it is the goal toward which we should persistently work. And the change will be greatly accelerated through the pressure exerted by the pulp mills in their efforts to acquire large tracts of land on which to grow their pulpwood. Whether the land be owned by the pulp company or by others who will make a business of growing pulpwood as a crop and selling it to the mills, the signs are plain that enormous areas in the Southern pine belt will be devoted to that purpose in the near future. That will call for good silvicultural practice on all such lands in order to assure satisfactory yields, and that will mean not only the suppression of forest fires but the total exclusion of grazing.

There is another forest industry in this region that utilizes large amounts of land—the time-honored "naval stores" industry, now centered in southern Georgia and Florida. In these two states and the southern part of South Carolina about 90 per cent. of the valuable naval stores (principally turpentine and rosin) are produced. It has been estimated that in this region 75 or 80 per cent. of the pine forests are controlled by men engaged in naval stores production. And it is in this naval stores area that a number of large pulp mills have recently been built. The pulp people have been getting some wood from the turpentine men in the form of worked-out trees, but they will find that they can not depend on this source for very much raw material. For a turpentine *orchard*—as such a property is usually called—is exactly what that name implies, it is more of an orchard than a forest and is as ill-conditioned to produce large and continuous crops of either saw-timber or pulpwood as a



CROSS SECTION OF BUTT OF FIRE-DAMAGED YELLOW PINE

NOTE SCARS FROM ALL FIRES AND SIGNS OF GRUB DAMAGE AND ROT, BOTH AFTER-EFFECTS OF FIRE. HALF THE CROSS-SECTIONAL AREA OF THE LOG IS WASTED.



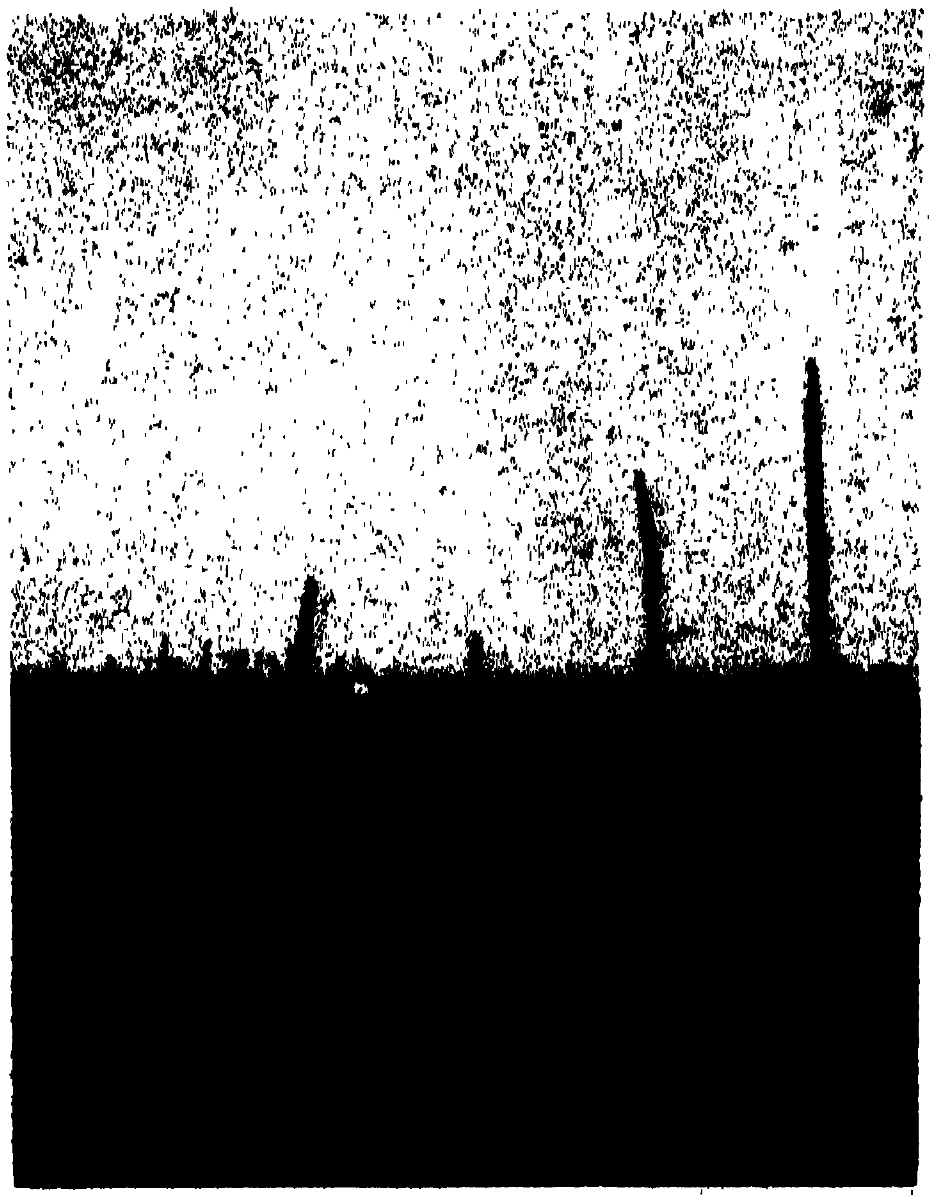
A TEN-YEAR-OLD PLANTATION OF SLASH PINE NEAR HOMBERVILLE, GA.
THIS PLANTATION IS ABOUT READY TO BE THINNED AND THE REMOVED MATERIAL WILL FIND A MARKET AS PULPWOOD AND FIREWOOD.

OLD FIELD STAND OF LONGLEAF IN SOUTHEAST GEORGIA
A THINNING HAS BEEN MADE, REMOVING MATERIAL LARGE ENOUGH FOR PULPWOOD. THE REMAINING TREES WILL PUT ON INCREASED GROWTH.

heavily grazed woodland. To get maximum production of naval stores requires an open, orchard-like stand of trees with full crowns. It requires twenty to twenty-five years for the slash and long-leaf pine to reach a profitable size for turpentining. From then on, by using the most improved methods, the trees may be profitably worked for twenty-five or thirty years. But a crop of pulpwood can be grown and harvested every twenty or twenty-five years. The pulp mills will find that they must grow their own timber or obtain it from people who make a business of growing it for them.

But there is plenty of land in the South for all the timber that could be profitably grown and all the live stock that could be profitably raised. With the cattle tick eradicated the natural conditions are highly favorable for the development of a flourishing live-stock industry. Moreover, pioneer days have passed and we are entering a new era in agriculture. We know that it does not pay to raise the kind of stock that is usually found grazing in the piney woods. Over a hundred years ago it was recognized by competent judges of live stock that the cattle which were brought up in our Southern woodlands were the scrubbiest of scrub stock, as most of them are to-day. In 1815 William Johnson, of South Carolina, a justice of the United States Supreme Court, in addressing an agricultural society in Charleston, spoke of the range cattle "that ordinarily disgrace our cowpens." To-day beef cattle of the pine lands are worth only one third as much as corn-belt cattle. And as for dairy cows, a present-day Carolinian who was brought up among the pine woods stock recently remarked to the writer: "At the best we'd get about a gill of blue milk a day from each critter."

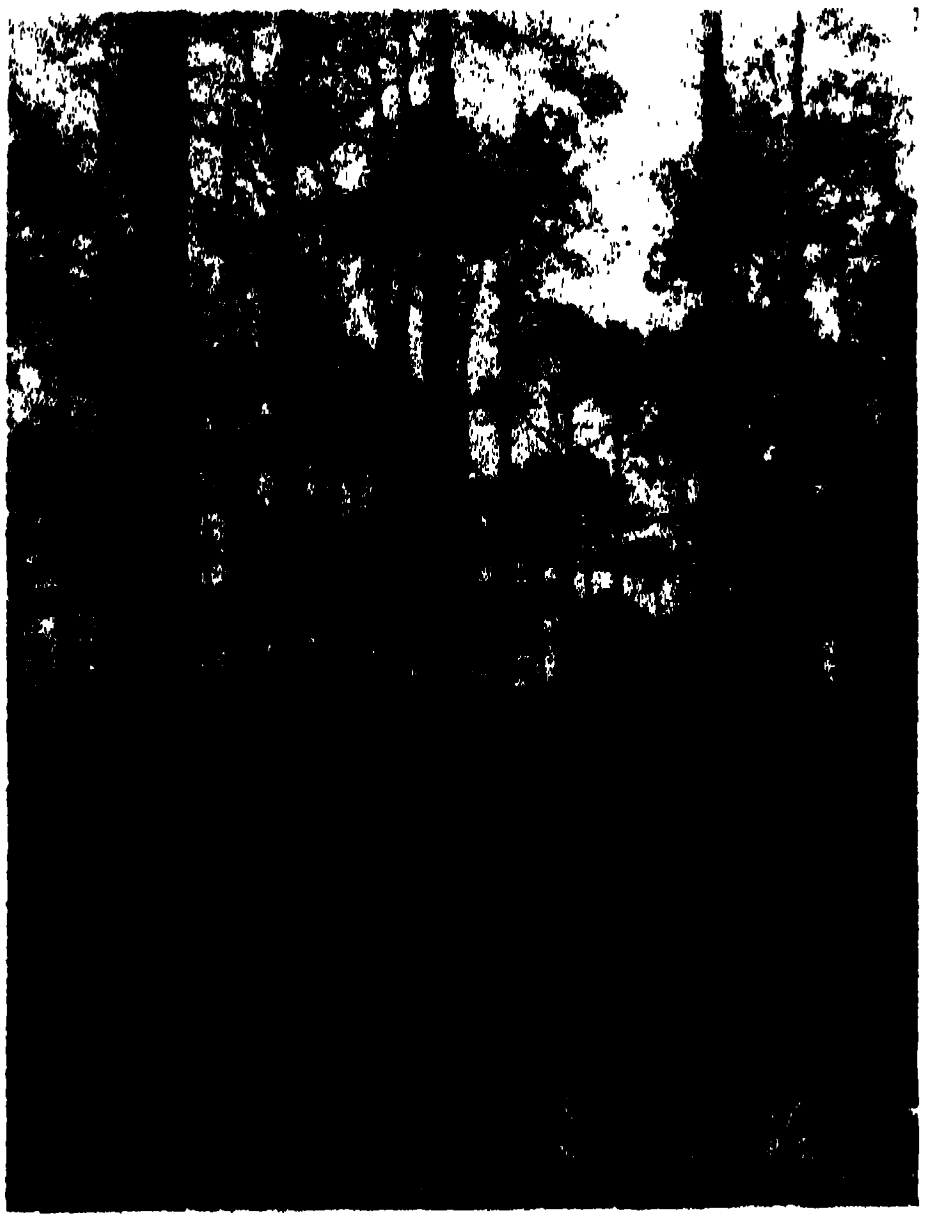
The plain fact is that ranging stock over forest land is a backwoods method, which may have been justified under pioneer conditions but can be justified



COMPLETE DEVASTATION
IN THE YELLOW PINE BELT OF CENTRAL LOUISIANA AFTER DESTRUCTIVE LUMBERING FOLLOWED BY FIRES. NO SEED TREES REMAIN; THE LAND WILL LIE BARREN UNTIL ARTIFICIALLY REFORESTED. TYPICAL OF HUNDREDS OF THOUSANDS OF ACRES IN THE COASTAL PLAIN.

A FIRE-KILLED POLE STAND
OF SHORTLEAF PINE IN ARKANSAS.

TYPICAL SOUTH GEORGIA POLE STAND WHICH HAS BEEN PROTECTED FROM FIRE.



AN OPEN VIRGIN STAND OF LONGLEAF ON THE CHOCTAWHATCHEE NATIONAL FOREST.

no longer. Successful live-stock raising to-day can be accomplished only by grazing the stock in permanent open pastures and by growing forage crops. The county agricultural agents in every Southern state are advocating permanent improved pastures, and the most progressive farmers and cattle men are providing them. Not only is the actual amount of forage much less in woodlands than in open pastures, but the feeding value of forage plants grown under forest shade is much less than if grown in full sunlight. It is commonly estimated that a good open pasture will support ten times as many head of cattle as the same area of woodland pasture, but the ratio will depend largely on the density of the woods. The more open the stand the more abundant will be the growth of grass, but the yield of timber will be proportionally less and the quality poorer. A well-managed forest in a humid country like the South will not support any grazing, for there will be no grass.

It is true that live stock are benefited by some shade in hot weather. This should be provided by single trees scattered here and there over the pasture, and by grove-like strips of trees along streams. Such tree-growth should be regarded as permanent pasture "fixtures" and never cut for timber.

The practice of forestry means the raising of timber in successive crops, and if our Southern woodlands be adequately protected from fire and properly handled, timber will be one of the South's most important and profitable crops. It will provide the permanent basis for large lumbering, paper and naval stores industries. But a goodly portion of this region should also be in permanent pastures, raising large herds of both beef and dairy cattle. The future prosperity of the rural South depends very largely upon the wise development of both these resources. There is plenty of land on which to develop both the South's magnificent forest resources and a splendid live-stock industry without mixing the two on the same areas to their mutual detriment.

SCIENCE PROGRESS THROUGH PUBLICITY

By AUSTIN H. CLARK

SMITHSONIAN INSTITUTION

SINCE the beginning of the present century scientific advance has been greater than in all the hundreds of years preceding—or at least since the discovery of fire and the first fashioning of tools. This advance of scientific knowledge is bringing with it certain elements of danger, for the further we advance in any scientific line the fewer are those able to follow the increasing multiplicity of detail and to understand the increasingly complex principles involved. Research workers are therefore running the risk of becoming isolated from the general mass of the population in our social order.

This risk is real. For unless any given group within a social unit is recognized as contributing to the material or spiritual welfare of that unit, sooner or later it will be in danger of elimination. The history of science in England before the Restoration and its development after the accession of Charles II, and the very varying status of scientific research in the different countries of the world today, show us that scientific advance, at least in certain lines, is conditioned by the attitude toward it on the part of the general mass of the population as reflected by their chosen representatives.

We also learn from history that a liberal attitude toward science may at any time change to a more or less restrictive or suppressive attitude. This has happened in recent years in various sections of the United States as well as elsewhere.

We live in a democracy. In a healthy democracy all groups within the population must do their share toward furthering the common good of all, in accordance with their special and diverse abilities. Each group must win and hold the confidence and respect of all the other groups. If science is to prosper and to advance, the population as a whole must take an interest in and appreciate the work done by our scientific men and women. The people must see in scientific work something of value to themselves. They must envision science as continually leading the way to better things—to an easier, safer, more satisfying existence.

Popular interest in science is twofold. In the first place, there is the purely material interest based upon the advantages to be gained in increased comforts, and in increased opportunities for broader social and other contacts, such as, for instance, those afforded by the automobile and by the radio. To these we may add the potentiality for economic betterment, and the increase in personal welfare and security resulting from advances in our knowledge of the several branches of science that collectively make up medicine.

In the second place, there is the interest that is wholly non-material. To every one it is a source of satisfaction to know that we are pushing ever forward into the realm of the unknown the boundaries of our knowledge. And as we do this, we are at the same time opening up new vistas of the unknown, beyond which we sense the vast realm of the unknowable.

We can never know everything. The more we learn, the more clearly do we appreciate the infinite extent of that which we can never know. Instead of gradually confining the human mind between barriers of facts and formulae, science leads us on to a more satisfying contemplation of the infinite.

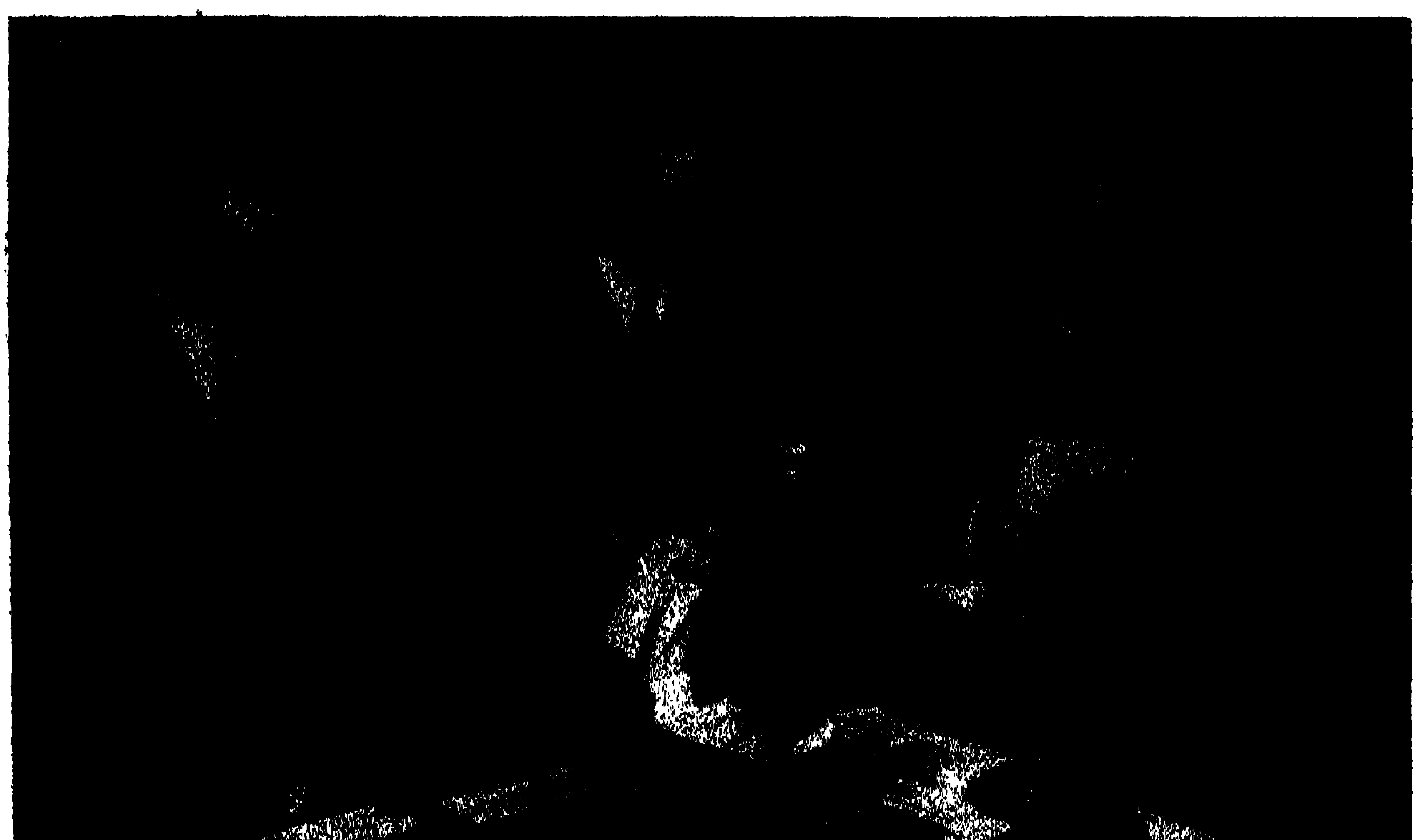
Only a few years ago this broadening

of the intellectual horizon was confined to those actively engaged in science, or closely associated with the students of science. And these alone appreciated the potentialities of scientific advance in its social and economic aspects. But now this knowledge is being broadcast to all our people so that every one may understand and every one may benefit.

This exposition of the advance of science is being carried out as a cooperative enterprise. Increasing numbers of our scientific men and women are willing to let others know what they are doing. By the members of the National Association of Science Writers their work is accurately interpreted and expressed in popular language that all may understand. Because of their importance to the general public, the accounts written by the science writers are laid before the public by the editors of our newspapers and our magazines.

This cooperation between the research workers, the science writers and the editors has proved of great benefit not only to the people, but to science itself. Frequently it has happened that a story written by one or more science writers has stimulated such general interest in a subject that a flood of additional information became almost immediately available, or further investigation was greatly facilitated as a result of popular demand. Without such an awakening of public interest it would have taken many years to have acquired the knowledge that we have to-day.

Out of the many cases available I shall take two that have occurred within the past few years, one showing how the diffusion of knowledge through the press



FOUR OF THE FIVE PULITZER PRIZE WINNERS

IN THE NATIONAL ASSOCIATION OF SCIENCE WRITERS; AT THE TABLE, LEFT TO RIGHT, MR. JOHN J. O'NEILL, SCIENCE EDITOR, *New York Herald Tribune;* MR. DAVID DIETZ, SCIENCE EDITOR, SCRIPPS-HOWARD NEWSPAPERS; MR. WILLIAM L. LAURENCE, SCIENCE NEWS EDITOR, *New York Times;* SEATED, BETWEEN MESSRS. O'NEILL AND DIETZ, MR. HOWARD W. BLAKESLEE, SCIENCE EDITOR, ASSOCIATED PRESS; MR. GOBIND BEHARI LAL, SCIENCE EDITOR, INTERNATIONAL NEWS SERVICE, IS NOT SHOWN. OTHERS IN THE PICTURE ARE MR. WATSON DAVIS, DIRECTOR, SCIENCE SERVICE, EXTREME LEFT; AND DR. SIDNEY S. NEGUS, MEDICAL COLLEGE OF VIRGINIA, EXTREME RIGHT.

has helped pure science, the other showing its effect on applied science.

In 1926 there was discovered at Folsom, New Mexico, in association with the bones of an extinct bison, an arrow-point of a type quite different from the usual Indian projectile point. In 1928 this discovery received much publicity in our press. In the spring of 1934 one of these so-called Folsom points was discovered near Richmond, Virginia. This find, announced in the press by the science writers, attracted immediate attention all over the country, with the result that many notices of the discovery of similar points were received at the Smithsonian Institution.

From these notices, verified by the specimens submitted, it was learned that arrow-points of this type are pretty widely distributed over the country, though chiefly east of the Rocky Mountains, and furthermore an extensive camping place of Folsom man—the now famous Lindenmeier site—was located in northern Colorado and brought to the attention of the Smithsonian Institution.

Thus our present knowledge of the interesting and unique Folsom culture, the earliest human culture in North America of which we have any evidence, has been pieced together almost entirely from facts brought to light primarily as a result of the work of the National Association of Science Writers.

Pure science is profiting more and more through the cooperation of the research workers, the science writers and the editors. The benefits of this cooperation have been even more marked in applied science. Let us take an example from the field of medicine. There is nothing that appeals to us more strongly than the alleviation of human suffering, and it is in this field that the science writers have done some of their most outstanding work.

Long ago it was noticed on battlegrounds that wounds infected with the larvae of blow-flies healed more readily than uninfected wounds. But this knowledge was not put to practical use until about a decade ago. In 1929 Dr. W. S. Baer published in the *Southern Medical Journal* a description of a new and unusual treatment for slow-healing wounds, such as the persistent and wide-spread bone disease known as osteomyelitis. The treatment consisted in placing sterile blow-fly larvae directly in the wounds that had failed to heal under other treatment. After a few applications of the larvae the wounds in general became cleaner, and healing began to take place.

Investigations were undertaken to determine the substance or substances in the secretions of these larvae responsible for the beneficial effect. One of the substances was found to be allantoin, easily produced synthetically.

In 1935 Dr. William Robinson published an account of healing in non-healing wounds resulting from the application of allantoin. This was at once given wide publicity by the science writers, and accounts of Dr. Robinson's work appeared in newspapers and other journals at intervals throughout the following year.

As a consequence of these accounts, a large number of physicians and surgeons obtained allantoin and used it clinically, and many inquiries were received from people who wished to treat themselves; furthermore, a number of chemical and pharmaceutical companies undertook the manufacture of synthetic allantoin, and of various preparations containing it.

This is an excellent example of how the science writers have aided in bringing into general use within a very short time a valuable curative agent.

The importance of the work of the science writers in this connection is emphasized by the fact that the use of allantoin had been suggested long ago. In 1912, before the inception of modern science reporting, Dr. C. J. Macalister in

an article in the *British Medical Journal* had reported the successful use of allantoin in the treatment of chronic ulcers. But his work attracted little attention at the time and was soon forgotten.

In August, 1936, attention was called to the remarkable healing properties of urea, another substance present in the excretions of blow-fly larvae. The science writers gave this discovery also extensive publicity, and urea is now receiving wide attention by the medical profession, with very encouraging results.

In the history of modern science writing there are many cases such as these. Science and the press are now united in a partnership that is becoming closer every year.

To every one interested in the advance of science it is a source of the greatest satisfaction to note that tangible recognition of the importance and value of the work of the members of the National Association of Science Writers is increasing. Honorary degrees and memberships in scientific societies and scientific clubs are being conferred upon them. No less than five of them have received the Pulitzer Prize for the excellence of their work. A few months ago the association as a whole was honored by the award of the Clement Cleveland medal for outstanding work during the preceding year in the campaign to control cancer. It may be of interest to add that many of our research workers, as well as interested laymen, are now with complete confidence keeping themselves in touch with scientific advances in lines other than their own by reading the notices in the daily press.

Now it is self-evident that the increasing success of the science writers in presenting science to the American people in accurate and readable form has been made possible by the increasingly sympathetic attitude of the enlightened editors of our newspapers and magazines, who see more and more clearly that science, accurately displayed in their pages, is not only of interest but also of value to the public.

With our corps of able science writers and our intelligent and appreciative editors we may hopefully look forward to the future, provided we who are engaged in scientific research do our part. We must continually bear in mind that we are an integral part of the society in which we live, not a select or selected group, and that others are quite properly interested in what we do, just as we are interested in what our fellow citizens are doing.

But in connection with our scientific work we speak a dialect incomprehensible to most of the other elements of the community, and our method of thought is along channels with which the average man is almost wholly unfamiliar. So we need interpreters. These interpreters we have in our science writers who understand our language and also the language and the mental attitude of the general public, with which we are more or less unfamiliar.

Our duty to the community in which we live, to science, and to ourselves, is to take the public completely into our confidence and to provide the interpreters—the science writers—with all the material they can use. In bringing science to the people we have already made enormous progress. The groundwork is now complete; but much still remains to be done to perfect the superstructure.

OCEAN PASTURAGE IN CALIFORNIA WATERS[1]

By W. E. ALLEN

SCRIPPS INSTITUTION OF OCEANOGRAPHY OF THE UNIVERSITY OF CALIFORNIA

FOR ages, seafaring men have had their interest stirred, at certain times and places by conspicuous conditions of the sea due to the presence of microscopic plants (phytoplankton). Most often, their attention has been attracted by very distinct discolorations ("red water," "brown water," "yellow water," etc.), although the odor of sea water has been strongly prominent also sometimes ("stinking water"). In addition, there have been times and places when fishermen have had trouble in handling their nets or gear because of coatings of slimy material consisting of microscopic plants. Such experiences alone are sufficient to raise questions concerning the causes and relationships of the observed conditions.

In more recent years, because of increasing attention to details of ocean characteristics, less conspicuous occurrences and displays of phytoplankton phenomena have led to comprehensive studies of the microscopic plants and their activities. From such studies it has come to be understood that phytoplankton distribution in seasons (or other periods), in depths, in localities and in latitudes has direct relationships to movements of air and water masses (regular and irregular, systemic and turbulent), and that it both influences and is influenced by turbidity, density, temperature, light, dissolved substances, co-existent organisms and indefinite numbers of other chemical, physical and biological characteristics of sea water. In particular it is generally recognized to-day that phytoplankton constitutes the basic food supply (ocean pasturage) which directly or indirectly furnishes sustenance for commercial fishes and other animals at the same time that it draws much of its own sustenance from them. Not only so, but phytoplankton furnishes much of the food used by sedentary animals useful for human food (oysters, etc.) or harmful to human enterprise ("fouling organisms" so injurious to ship bottoms and other structures exposed to attack).

As recently as 1919 practically nothing was known concerning phytoplankton in the Pacific Ocean. Indeed, an authoritative paper published in Philadelphia as late as 1927 commented on the small numbers of kinds of diatoms and their thinness of population in the Pacific, although local investigations were already showing the contrary fact for this most important contributing group. Because of the necessity of knowing names and identities when discussing or investigating the relationships of any natural object or group of objects to conditions in the sea much time had to be given to mere identification and naming of specimens in the first few years of researches at the Scripps Institution of Oceanography at La Jolla, California. Thereby it was found that although more than two hundred species of phytoplankton organisms live in the East Pacific, less than fifty species ever become so abundant as to attract special attention, even from specialists. Although diatoms are distinctly most important in most years in most localities, the group of dinoflagellates sometimes takes a temporary lead in production of ocean pasturage.

Fortunately, while learning identities, it was possible to accumulate other

[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 122.

kinds of data concerning the components of phytoplankton. The records showed that no single species was ever able to hold the lead in production over a long period of time, rarely longer than ten days. Also it appeared that production tended to be best before July, although there might be a difference of a week or two in this tendency at two stations only a little more than one hundred miles apart. Twenty years of investigations have revealed that no two years were alike at either of two stations and that two years of unusually warm water (1926 and 1931) were poorly productive of both diatoms and dinoflagellates at both stations.

About three thousand catches by boat at offshore stations have shown that phytoplankton may reach notable abundance more than one hundred miles from shore and at depths as great as seventy meters, large numbers, however, rarely being taken below fifty meters. Sometimes many diatoms appear at lower levels though few at the surface, sometimes many appear at the surface when numbers are small below, and sometimes rather large numbers may be found at all seven of the levels sampled at a particular station. Unexpectedly, large numbers in good condition are taken sometimes from levels below large numbers in poor condition. As a matter of fact, no large numbers of specimens in dead or decadent condition have been observed below any dense population in vigorous condition, although one might suppose that many would die and sink.

A notable difference of abundance of phytoplankton between two stations indicates a difference between them in respect to chemical composition of the water, physical constitution of water masses, behavior of water masses, climate or meteorological conditions, or animal populations. If such a difference in phytoplankton populations does no more than prevent hasty or rigid conclusions and inferences from being asserted on the basis of close similarity of too few chemical or physical observations, it is worth something. When it confirms the validity of an observation of an unexpected difference in those conditions it becomes distinctly helpful. That is to say, microscopic plants naturally detect and respond to chemical and physical conditions of their environment which are too delicate for one to detect by routine methods in a laboratory. Therefore, proper attention to their responses to unnoted changes in those conditions may lead to correct interpretations or to changes in routine which lead to better if not to full understanding.

In some localities most of the oxygen in sea water is derived from the air. In other localities (or at certain periods) most of it is derived from phytoplankton. In the one case no immediate effect on the chemical composition of sea water is necessarily involved in the processes of introduction.

In the other case, incident and immediate changes occur in substances containing carbon, sometimes involving indefinite series of chemical changes in surrounding sea water. So far, no one has ever evaluated the contribution of oxygen by phytoplankton in the ocean although chemists, physicists and biologists are agreed that in the matter of oxygen transfer alone the microscopic plants hold a prominent place in the network of environmental influences. Although the twenty years of phytoplankton research have shown conclusively that periodicity of production and occurrence is not predictable for any restricted or specific place or depth level, they have shown that cloudlike aggregations of diatoms and dinoflagellates run a course of increase and development during which much might be learned about the influences of phytoplankton through oxygen production

(and consumption). While the requirements of trustworthy investigations of this problem under natural conditions may be too expensive at present, it is none the less true that the opportunity exists.

Similar statements may be made concerning investigations of occurrence and distribution of carbon, phosphorus, nitrogen and their compounds as well as other elements and substances not mentioned so frequently. Although many people seem to feel confident that relationships of influences of temperature may be easily detected, described, and evaluated, it is more probable that a clear understanding of any but the grossest manifestations of temperature conditions is very difficult to obtain. Still, there is no doubt of the fact that adequate phytoplankton data may aid substantially in understanding coincidental phenomena of temperature. Probabilities seem to be even better for such influences as viscosity, density and light.

Repeated cruises continue to show that phytoplankton abundance has a recognizable relationship to turbulence, upwelling, oceanic drift and to major and minor currents. It is entirely reasonable to expect that understanding of these relationships will improve rapidly as more data of the same kind as those yielding these results are accumulated.

So far, inshore and offshore conditions are not clearly understood as to manner and degree of influence but much is apparent already in fact. For example, certain species which reach abundance offshore are rarely noticeable inshore (and *vice versa*). Also, certain localities near shore appear to be more productive at certain periods or seasons while certain localities offshore appear to be more productive at other periods or seasons. Here there can be no question that familiarity with phytoplankton populations in their native habitats will help to clarify these relationships either when time and effort can be spared for them directly or as data accumulate otherwise. Possibly even better progress can be made toward understanding of characteristics of deeps and shallows by giving careful attention to phytoplankton relationships in or about them.

Practically nothing is known concerning the more direct effects of run-off from land, not to mention the indirect effects. Even Gran appears to have rejected an earlier opinion that run-off enriched sea water, but it is surely reasonable to suppose that this enrichment ensues, nevertheless. Whatever the facts may be, it seems certain that the phytoplankton must be depended upon for evidence leading to a final solution. Doubtless this solution will be delayed a long time because of cost of specific researches required by it, but the phytoplankton data accumulated by the Scripps Institution affords a sound foundation upon which to base the necessary investigations, not only of the nutrient influences of run-off but also of dilution and sedimentation influences.

To geologists (especially petroleum geologists) plankton diatoms are highly interesting because of their relationship to problems of oil-producing sediments. If one can learn why diatom frustules are deposited here and not there, and why sometimes no diatom deposits can be found at or near localities which are known to yield them abundantly, he may be able to account for some of the vagaries of deposition. Some of the observed conditions of occurrence suggest the probability that many diatom frustules dissolve during long support or transport without sinking to the bottom, thus maintaining in the water a fair supply of siliceous material to be used by their own kin.

So far Scripps Institution work on phytoplankton has contributed nothing to direct knowledge concerning the con-

tinuous series of changes of organic wastes in the sea. We know that the little plants must use other things besides carbon dioxide, but we do not know what forms of the various substances are most valuable in their activities, nor how they meet fluctuations in amounts of preferred materials. However, the records of occurrence of phytoplankton bring necessary information to the point where intelligent selection of species and localities may be made for conducting observations.

Concerning relationships with other organisms much that has been said above will apply. However, it seems probable that phytoplankton data are even more important for any one who undertakes to identify and trace food chains (*e.g.* diatoms, copepod, sardine, mackerel, squid; or diatom copepod, hydroid) involving either free-living or sedentary animals. Still, the food relationship is not the only one. For example, researches indicate that phytoplankton may become so abundant sometimes as to seriously injure many surrounding animals, possibly by mere crowding, possibly by clogging of the gills, possibly by direct poisoning in some cases.

CENTRALIZED EDUCATION

I HAVE no hesitation in saying that the complete domination of education by the state in Germany was what made it so easy, when her war lords had decided to embark upon a career of world conquest, to obtain the aid of her university professors, philosophers, and historians alike, though not all of them, in spreading *der tag* psychology throughout the whole of her population. I myself saw this happening in the nineties in Germany, and in 1907 I heard the man they called their greatest historian, Edouard Meyer, before 2,600 students in Mandel Hall glory in war and conquest as the finest developer of a people. *That was what made the Great War.*

Today it is very much worse because the centralization and control of the educational system enables the gangsters who have seized control of government to use the whole machinery of education, including the press and the movie as well as the schools, for *indoctrination*, instead of education, for substituting for the free growth of knowledge the rank growth of ignorance of every fact or idea which could militate in any way against the interests of the gangsters and the continuation of their power. It was because Spinoza saw the inevitability of this result of a centralized educational system that he opposed completely the placing of education in the hands of the state.—*Address by Dr. Robert A. Millikan, California Institute of Technology at Pasadena.*

THE ORIGIN OF OUR NUMERALS

By JOHN DAVIS BUDDHUE

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We are accustomed to use two kinds of numerals with very different histories, the Roman and the so-called Arabic numerals. It is probable that neither of these names is the correct one, for the Roman numerals appear to be of Etruscan origin, with perhaps a trace of Greek, while the Arabic figures are really of Indian origin.

To begin with the Roman numerals, the first three are obviously a representation of a numerical idea by making an appropriate number of lines. Four is for some reason written as 5 – 1. The use of V for five is said by some to be a symbol of the hand held up, one arm representing the thumb and the other, the fingers bunched together. According to this line of thought, X is simply two V's, one of them inverted. Similarly, C is an abbreviation of *centum* = 100, and M is *mille* = 1000. Unfortunately, this system does not account for D = 500 and L = 50, since neither of these is the proper initial letter. Consequently we must look for something better as an explanation.

According to the Etruscan system of numeration, 100 was represented by a circle divided into quadrants. By removing the circle X was left and used to represent ten. Proceeding along these lines, V was obtained by dividing the X in half, exactly the reverse of the above incorrect system of derivation.

For 1000, the Etruscans used a circle with a vertical line dividing it. This was also adopted by the Romans. Half of the circle gave D, or 500, and another kind of division gave an inverted T which was eventually changed into L, or 50, because it could be written with one continuous line. As for M, we must leave the Romans and Etruscans and examine some samples of old printing. For some reason, no one seems to have thought to cast type for the Etruscan symbol of 1000 and a makeshift was used thus: CIↃ. This was rather cumbersome and was largely abandoned in favor of M which bore more or less resemblance to the true sign and also was the initial letter of *mille*. C was originally a circle, but that was liable to cause confusion with the letter O; therefore, C was put in its place because it was the initial of *centum*.

The Roman numerals therefore are hardly alphabetic although the suggestion has been made that the signs for 10, 50 and 100 were derived from the Greek letters Χ, Ψ and Φ, respectively.

The Indo-Arabic numerals have had a much more extensive history and few people would recognize them in most of their earlier forms. Their ultimate origin is unknown but some trace them back to the Egyptian Heiratic and therefore to the Heiroglyphic. A better suggestion is certain letters of the Indo-Bactrian alphabet. It will be noticed that the phonetic values of these letters are given. This is to call attention to the fact that they are really initial letters for the number words in Zend or Sanskrit or both. Thus 4 = chathwar (Z), 5 = panchan (Z), 6 = shash (S), 7 = saptan (S), 8 = ashtan (S), 9 = navan (S, Z) and 10 = dasan (S, Z). Consequently it would seem that those old Aryans began to write numbers by drawing a series of short lines just as the ancient Romans and Egyptians did, but they soon got tired of that cumbersome method and decided to use the initial letters of their number words instead. That at least was an improvement over the Greek and Semitic system of using letters for numbers

that bore no relation to the sounds of the number words.

Whatever their origin, the earliest known use of the prototypes of our numerals are found in the Nana Ghat inscription of India. Later came the Cave inscriptions which were made some time early in the Christian era.

It is important to note that positional notation was unknown until, probably, some time in the sixth century A.D. That is, there was no zero, and ten, eleven, etc., were written with separate symbols. But eventually some unknown mathematical genius invented a zero and the positional system was born. The invention of zero was probably a result of the abacus or a similar device such as a smooth board covered with sand. The number 204 would be written by making three columns. In the first two lines would be made, the second would be left blank and four lines would be made in the last column. No doubt it occurred to this unknown mathematician that the same result could be accomplished by using numerals, provided that there were a symbol to denote the empty column. Thus zero was born and named *sunya* (empty, blank).

At any rate, the numerals together with zero were adopted by the Arabs. They probably learned them from some mathematical tables brought to Bagdad by an Indian ambassador in 773 A.D. From there the knowledge of them spread slowly over the whole Arabian world. There were two principal variations of these numerals, the Eastern and the Western or Gobar. The latter word means dust and suggests that some sort of sand abacus was known. This variant was used in Spain by the Moors and in Africa. It is the prototype from which our numerals were derived and the resemblance to our modern numerals is by now quite clear.

At the time of the introduction of the numerals into Europe a modified abacus was used in which numerals replaced the counters but zero was represented by an empty column again. This was used at Rheims about 970–980 by Gerbert, who later became Pope Sylvester II, and by the eleventh century it was well known. There is no direct evidence to show where Gerbert learned of it. According to William of Malmesbury he stole it from a Spanish Arab, but this theory is usually regarded as a mere fable. Still there is no known use of the abacus in Europe at an earlier date except in the *Geometria* attributed to Boëtius. If this book is genuine we have direct evidence that somehow the Indian numerals got into Europe in the fifth century, and Gerbert only resurrected a system forgotten for 400 years, more or less. If this is true, then how did Boëtius learn of it? He himself describes it as the system of the Pythagorici. This suggests that the old Indian numerals along with the abacus was introduced into Alexandria some time before the fourth century A.D. when communication between India and Europe ceased. In fact the close resem-

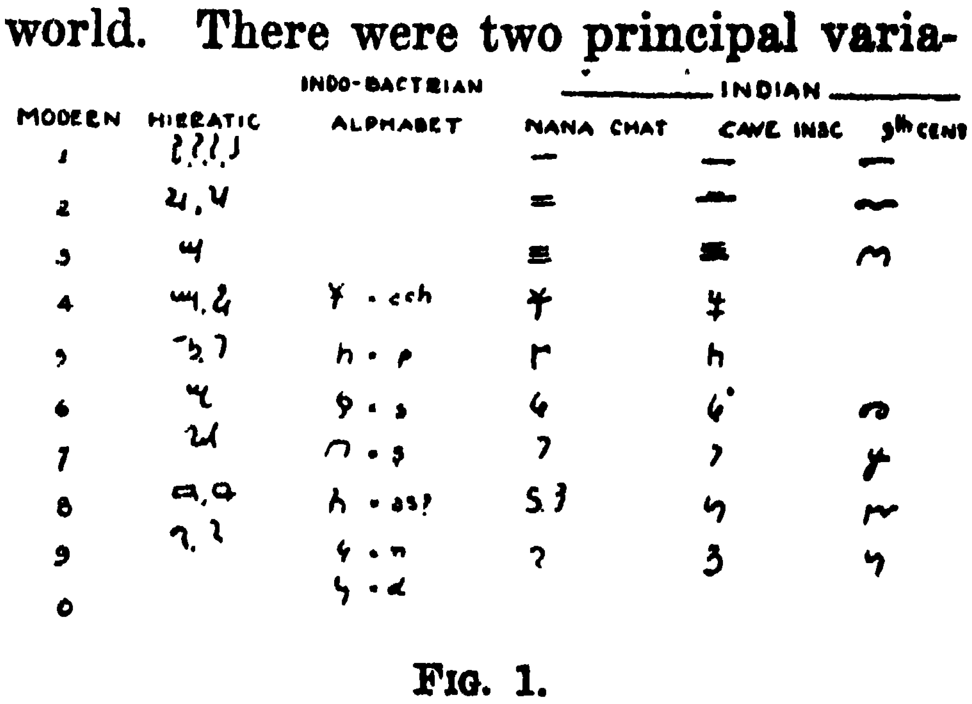

FIG. 1.

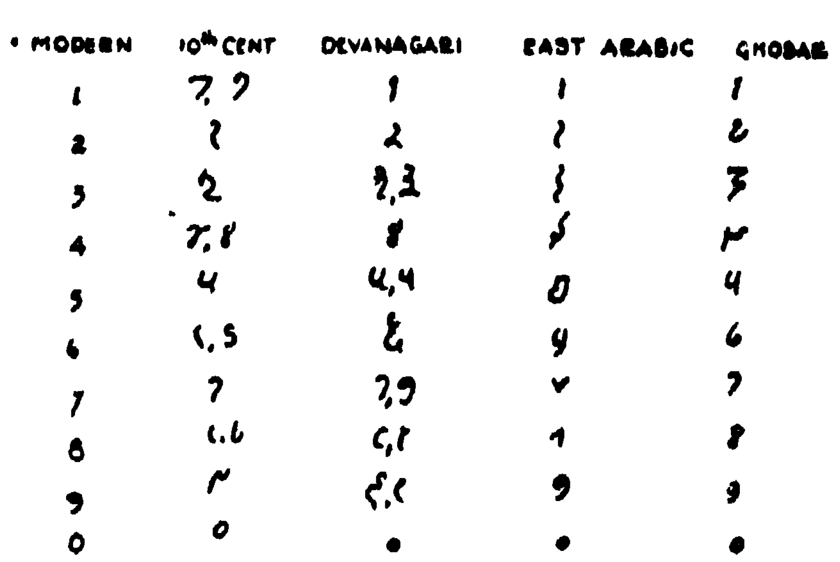

FIG. 2.

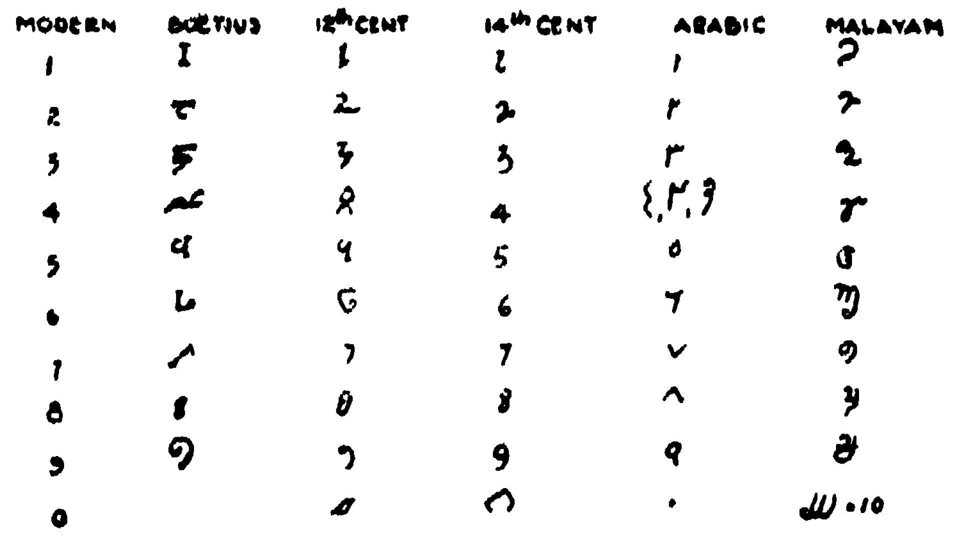

FIG. 3.

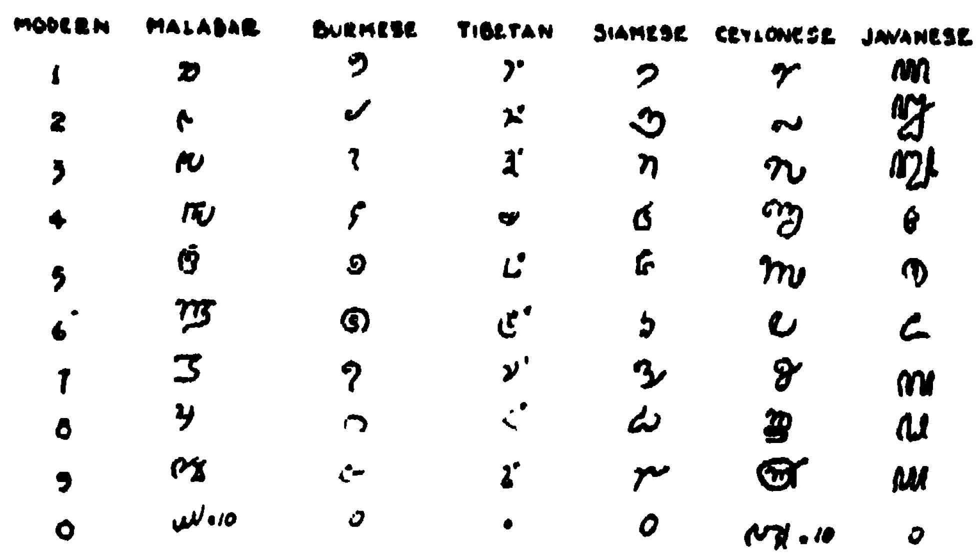

FIG. 4.

blance between Boëtius' figures and the Gobar Arabic has led F. Woepcke to believe that the western Arabs adopted their system from Boëtius before the Indian method with a zero reached them. There are many difficulties to this view however, among which is the difficulty in explaining the rather close resemblance between the Gobar and the Eastern Arabic system if the two had been separated for some hundreds of years. Moreover, the authenticity of the Geometria is not established, and it is quite possible that Gerbert or some one else obtained a partial knowledge of the abacus and the numerals from the Arabs but failed to obtain, or to understand, the idea of zero.

Later on the zero was added and the abacus fell into the discard. Few people know of it now, except as a plaything for children. The word zero is of Arabic origin. When the Arabs obtained the numerals from the Indians they translated the Indian *sunya* into their own word *sifr* with the same meaning. When the numerals were introduced into Italy, *sifr* was Latinized to *zephirum*. This happened some time near the beginning of the thirteenth century. Various changes occurred during the next hundred years ending in the word *zero*.

However when Jordanus Nemarius introduced the Arabic system into Germany he kept the Arabic word but changed it into *cifra*. This word was retained and used as late as the time of Gauss. In English, *cifra* became *cipher* and in other parts of Europe we find *chiffre*, *ziffer*, etc. However, there was a strong tendency for these words to be taken to mean "numeral" and not "zero." The learned knew perfectly well the true meaning of the word, but the common people did not, and as a result a great deal of confusion arose. In fact, the word even came to signify a secret sign, hence our word *decipher*. At last the confusion was removed by the adoption of the Italian word zero.

It must not be imagined that the transition from the abacus system used by Gerbert to the positional numeration of the present day was easy. It was not. There was a battle raging between the abacists, who defended old tradition, and the algorists, who preferred the newer system, that lasted for 400 years, from the eleventh to the fifteenth centuries. In some places the Arabic numerals were not allowed to be used on official documents or were even prohibited altogether.

The Eastern Arabic numerals had little to do with the development of the sytem we use although they sprang from the same source. They did give rise, however, to the present-day numerals used by the Persians, Turks, Arabs, in fact, any one using the Arabic alphabet. In the figure it will be noted that three forms are used for the numeral four. Of these, the first is used by the Malays, the second by the Arabs and the last by the Persians. Otherwise, they are the same everywhere in the Mohammedan world.

I give also the Sanskrit and other oriental numeral systems, all of which are derived with more or less elaboration from the same source as our own, namely, the old Indian numerals. Some of them still retain a separate sign for ten.

EMERGENT RACES AND CULTURES IN SOUTH AMERICA

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THE tropical lowlands and low plateaus of South America—often referred to collectively as the Tropical Forest Region—constitute about half of the land surface of the southern continent and the largest continuous natural area in the Western Hemisphere. Yet this vast territory is one of the most sparsely inhabited of the globe and one of the least "exploited" in terms of human values, economic or otherwise, either by its natives or by outsiders. Therein seem to lie a group of scientific problems awaiting investigation with which anthropologists are particularly fitted to deal.

Americanists have hitherto been primarily concerned—and legitimately so—with archeological studies, historic reconstructions and ethnographic investigations of the aboriginal racial groups, cultures and languages of this part of the world. It is unlikely that any qualified judge would seriously object either to the aims or to the results of the larger portion of this type of work. And all anthropologists would doubtless agree that, far from being outmoded or completed, investigations of the traditional sort have only begun the great task which must be accomplished if we are to have comprehensive answers to the many questions of aboriginal racial and cultural development which demand explanation in this region.

On the other hand, it would be strange, indeed, if cultural anthropologists, of all people, were unaware of or indifferent to cultural and social developments taking place in the world of contemporary affairs. Recently public interest in many quarters, and particularly that of responsible leaders in the United States, has been increasingly attracted toward South America. We need not analyze nor judge the motivations of these interests here. But the fact is evident that business and financial experts are bestirring themselves over the future of markets, production and the development of resources and trade in South America. Statesmen ostentatiously strive for new modes of political collaboration. Military strategists have evinced a serious concern with the problems of defense and attack of the Americas. Cultural exchange between the various nations of the Western Hemisphere has been, at least formally, increased and placed on a higher plane. Scientists from many disciplines are enlisted to some extent in the formulation and solution of newly significant problems.

Any program of intelligent planning for human adjustment either for the present or for the future must rest upon sound information concerning the physical composition and cultural and social development of the population concerned. In providing information of this kind it seems that anthropology can make a contribution of tremendous significance in South America. It is perhaps not the function of the anthropologist to enter partisan controversies, but he does have the obligation and the techniques to provide a reliable basis of data upon which politicians and business men, for example, may act if they will.

It would not be difficult to document the view that much of the current thinking concerning South America is based

upon lack of realism regarding the actual anthropological situation in the southern continent. Such documentation would consist of the citation of current commonplace utterances which, while widely diffused, smack of the grossest ignorance. Thus in the United States it is not uncommon to speak of Latin American society as resting primarily upon somewhat "debased" Spanish and Portuguese institutions. We tend to think of the nations to the south in terms of an industrialized urban society supported by family homestead farming, which characterizes much of our own country, and to judge them in these terms. Misconceptions of a similar nature are not confined to the United States, but are likewise predominant in many South American capitals and centers of civilization with respect to conditions in the outlying regions. In my own experience I have found in various capitals the foggiest comprehension of realities concerning the interior and the difficulty of finding reliable guides and information is familiar to most travelers into the interior. Thus in 1934, at least, the views of the intelligentsia and government experts of Guayaquil and Qnito concerning the Ecuadorian Oriente could properly be described under the heading of folk tales and mythology. Few even of the permanent residents of Georgetown and the coastal region of British Guiana in 1933 had any more precise notion of the interior of their own country than they had of the interior of New Guinea, with which it is so often confused by ordinarily intelligent persons in the United States. The separatist tendency of the Peruvian montaña, with Iquitos as its center, is notorious and was in large part responsible for the Leticia incident—all largely due to ignorance in Lima concerning the eastern part of the country. As Beals says, "South America for the most part is a peripheral population, a seacoast population. The interior still has to be properly settled and exploited."

Let us consider in more detail the interior and particularly the largest and least known portion of it, the tropical lowlands and low plateaus. It is estimated from data by Zon and Sparhawk in "Forest Resources of the World," that from 40 to 50 per cent. of the continental area of South America is forested, and that by far the greatest portion of this forest cover is of the tropical lowland or jungle type. Southern Chile is the only region of extensive forest outside the tropical zones, and the Chilean forest is comparatively insignificant in terms of square miles. Here we may focus attention primarily on that portion of the jungle area comprised within the drainage of the Orinoco and Amazon, plus the Guianas. The area thus defined (Amazon-Orinoco-Guianas) is far larger than any other in the New World, covering some 3,240,000 square miles, or nearly 46 per cent. of the land area of the continent. Considerable portions of this vast province are only lightly forested, and some of it is plateau country (*e.g.*, southern Guiana, parts of Matto Grosso, etc.), but the major part is typical jungle.

Anthropologists have been primarily concerned with the aboriginal tribes of this area, and while a vast amount of detail remains to be recovered, we must face the fact that the native population is relatively small, probably not more than 300,000 to 500,000 at the most, and that the density of population of all types is considerably less than one per square mile. Furthermore, the Indian population, or a large part of it, has been exposed in varying degrees to contact with Europeans for about 400 years. In spite of this scarcity of population, since the collapse of the rubber boom in the second decade of this century, the tropical lowland area has remained one of the largest blank spaces outside the

polar regions on the face of the globe, not only from the point of view of population density, but also from that of cultural importance in terms of a world system dominated by Western civilization. Nevertheless it is open to doubt that this condition will long continue in a world dominated by expansionist economic systems and containing certain societies seeking "living space." The Belgian Congo, a smaller but environmentally analogous region, supports a population of over ten million with an estimated density of about 12 per square mile, according to the recent comprehensive "An African Survey," edited by Lord Hailey. In view of the fact that the African tropical forest area, while generally similar to that of South America, is if anything a more rigorous environment for human life, it hardly seems that the present relative unimportance of the Amazon-Orinoco-Guiana region is to be explained entirely on the basis of environment, but rather in terms of deficiencies in human stock and culture.

It is generally conceded that the tropical lowland area of South America is a source of considerable potential wealth in raw materials. Yet it receives little attention from social scientists other than ethnologists interested in primitive tribes, and nearly half of South America is thus written off as of small immediate or future importance to human affairs. The justification for this neglect usually follows these lines: (1) Natural resources, while abundant, can not be economically exploited, due to inaccessibility, smallness and lack of organization of the labor force and unprofitable condition of world markets. (2) The standard of living of the inhabitants is too low to permit profitable economic relations with nations of the middle latitudes, other than of the crude exploitative type. (3) Experience has shown that permanent white populations do not prosper in the low wet tropics, apparently in large part at least because of adverse reactions to the climate, so that such areas can not be looked upon as future regions for settlement from Europe or North America.

These arguments seem to me to be predicated on the traditional European imperialist attitude that the low tropics are of value only as reservoirs of raw materials to be exploited by a handful of white masters who use a socially and economically depressed native population as a labor force, primarily under the gang system on plantations or in mines. In such a set-up the whites are maintained in small numbers and temporarily by capital and cultural imports from the mother country. And the natives are persuaded or forced to depend upon home-country manufactured goods. According to this traditional view, therefore, a tropical region which does not contain a large, hardy and amenable native population, together with other conditions necessary for the usual extractive exploitation, is considered of no potential importance. It is not surprising, then, that tropical lowland South America has remained uninteresting to old-fashioned capitalist imperialists.

The possibility has never seriously been considered, so far as I am aware, of the emergence of a blended racial type and of a blended culture capable of developing cultural and economic relations of an independent and mutually profitable character with the nations of the middle latitudes. It is this possibility which I believe anthropologists could investigate with advantage to all.

The dream of large-scale permanent white settlements in the low wet tropics has been dissipated by recent investigations and by several centuries of experience. A. Grenfell Price has most recently summarized the evidence on this matter in "White Settlers in the Trop-

ics," and the 1939 report of the British Guiana Refugee Commission to the Advisory Commission on Political Refugees appointed by the President of the United States concludes that experimental colonization by whites in that colony is feasible, but only in a comparatively dry and non-forested savannah and hill district. Without citing more of the voluminous literature on this subject we may say that the prospects of a pure white society in the low wet tropics of South America appear to be remote. Likewise it is doubtful that a pure Indian society will occupy the region in the future, if for no other reason than that the process of extermination and intermixture with elements of white or negroid ancestry, which has been proceeding inexorably for four centuries, shows no signs of abating. The northeastern region of Brazil is now occupied by a mixed combination of white (Portuguese), negroid and aboriginal Indian elements, the sociological and historical aspects of which have been ably studied by Gilberto Freyre, among others. Says Freyre in his "Casa Grande e Senzala," "The Portuguese triumphed where other Europeans failed. The Portuguese was the first society of modern times constructed in the tropics with national characteristics and qualities of permanence. . . ." These results were, according to Freyre, obtained by devoting first and foremost energy toward the creation of wealth in Brazil itself, rather than to its extraction, and also by the borrowing and recombining of many Indian traits, "making use of the indigene, particularly the woman, not only as an instrument of labor, but also as the basis for the formation of a race of mixed bloods." For other parts of the lowland tropics we also have a sufficient number of scholarly observations of a descriptive, not a metrical type, on race mixture to indicate the general outlines of the process which seems to be taking place.

The first suggested line of research for anthropology, then, would be in the physical anthropology of the race mixtures of the tropical lowland region. Not only do we need information of a scientific, metrical nature concerning the actual somatic types which are emerging from the blending process, but we would also welcome psychological and medical data. Are the new types, like their Indian and Negro forebears, capable of resisting the tropical climate which seems to be so injurious to permanent white occupation, and at the same time have they inherited the "nervous energy" of their white ancestors? In short, is a stable, physically adapted population developing in this region which will be able to grow and to develop a social and cultural life of its own, free from domination of the middle latitudes but capable of carrying on reciprocal relations with the cultural centers of the temperate zones for the mutual benefit of all? There are many indications that such a development is taking place, but only scientific anthropological studies will enable us to grasp its true significance and to estimate its trend in the future.

The problem of *cultural* blending is of equal importance to that of racial blending, and herein lies the second group of problems to which anthropology should be able to contribute. There can be no dodging the fact that the aboriginal cultures of this region will be either modified or absorbed. Every one is familiar with the fact that the Western civilization of the middle latitudes is not easily transplanted to the wet tropics. In those instances where European and American material cultures is existent in the wet tropics, as in the Panama Canal Zone and in the colonial cities of certain western powers, it is well known that it is either extensively modified or it is maintained uneconomically by heavy financial support from the home country. And the "decay," as it is

sometimes called, of Western standards of conduct in the tropics is notorious, and has been extensively described both in fiction and in serious scientific reports. To anthropologists familiar with the general principles of the culture-environment relationship it is unreasonable to expect that European and American culture can be transplanted bodily and *in toto* to the low wet tropics, except in small centers maintained at considerable expense for strategic or political reasons.

Yet we must grant that the world as we know it is operating more or less in consonance with deep-lying fundamental principles which are part and parcel of this European-American culture or Western civilization. Whether we like it or not, we must recognize the existence of capitalist economics (whether privately or state controlled), nationalistic politics, monogamic marriage and small family units, machine technology, dependence upon artificial sources of power, literacy and rapid communication, and all that these words imply. And it is perfectly apparent that the indigenous cultural systems of the Amazon-Orinoco-Guiana region are in most respects inherently unfitted to "get along" with a Western civilization containing these complexes and drives. While the complexion of Western civilization may change with altering political or military fortunes, it seems unlikely that the basic complexes mentioned above will disappear completely from the world system for many decades or even centuries, barring a total collapse and "return to barbarism." Therefore the problems of this area seem to boil down to the following terms. European and American culture, adapted to middle latitude environments, can not be transplanted or borrowed *in toto* in the low tropics of South America. On the other hand, the indigenous cultures, although providing a material adaptation to the environment, are incapable, without radical reorientation and modification, of gearing into a world system dominated by Western civilization. It is the task of anthropology to investigate the actualities and the potentialities of an emergent civilization in this region, adapted to the environment, but capable of standing on its own feet in the world arena. The instability of the native situation under the old imperialist exploitation during the depression was apparent to many observers, of whom Earl P. Hanson was perhaps the most articulate in a number of articles and in his book "Journey to Manáos."

The task of the anthropologist with respect to these problems might be phrased in terms of the following questions. Is there any evidence that a culture, combining certain elements of aboriginal cultural adjustment (*e.g.*, house types, food, clothing, etc.) with values and techniques derived from Western civilization, may be arising? Japan, for example, represents a society which has adopted certain Western traits of culture (*e.g.*, capitalist economics, machine technology, military tactics and weapons, etc.) without loss of many indigenous cultural elements. This blending process has given Japan a position of independence and reciprocal function in the world. Is a similar process developing, or capable of developing, in the Amazon-Orinoco-Guiana region? We do not mean to suggest that an exact parallel with Japan will be found, but this case is mentioned in order to indicate that what may happen in one society may, in a general way, occur elsewhere, namely, in South America.

As with race mixture, so also with cultural mixture we are not dealing purely with hypothetical possibilities. A considerable number of trained observers have described various aspects of acculturation within the region. Nordenskiöld dealt in a number of publications with early post-Colombian European contacts with natives and traced the diffusion of certain European culture

elements, using primarily the linguistic approach. F. Keiter published a survey of acculturation in the Upper Amazon basin based on G. Tessmann's material. Baldus and Petrullo have provided some information on the region of the Upper Xingu and Matto Grosso, Snethlage on Eastern Bolivia, and other authors have dealt in summary or passing fashion with other portions of the area. The present writer's personal observations from Eastern Ecuador and Peru to the Guianas confirm the impressions of other observers that the native cultures are disappearing, not into a European culture as we generally understand it, but into a synthesis composed of European and native elements. The time has now come to proceed from these somewhat random studies and impressions to a systematic consideration and investigation of the whole problem.

Perhaps the emergent cultures of the Amazon-Orinoco-Guiana region could best be studied through the regional approach, using some of the concepts and techniques developed by American geographers and sociologists, together with ethnological methods of acculturation study already proven successful by anthropologists. In the Amazon Valley one region of this type is that comprising Eastern Peru and Ecuador, with its cultural center at Iquitos. The regions of Manáos, Pará and Santarém, the Upper Orinoco, Orinoco delta, etc., might be similarly studied. And with the anthropologist we might expect other social scientists, particularly the geographer and economist, to cooperate in investigations of a more specialized nature.

Once in possession of the data concerning racial and cultural change and blending in this region, scientists as well as "practical men" concerned with human problems would be in a better position to shape the future course of relations with South America, and policy-makers in South America itself would have a firmer basis on which to proceed. With respect to population problems, we might call attention to the present overcrowding of the colored population in parts of the West Indies, for example, Puerto Rico and Jamaica. It is conceivable that scientific studies of the lowland tropics of South America would indicate this to be a land of opportunity for colored migrants.

In emphasizing the opportunities for research in the lowland tropic region we should also point out that similar anthropological studies are applicable to other portions of South America. Particularly in the Andean republics it seems that nativistic elements, their blending and cultural adaptation, will present important problems for the future. The rise of Aprismo and of self-conscious native literary movements in these areas are only two indications that old conditions are changing.

In short, the argument of this paper is that human resources are of equal importance with "natural" resources in our relations with foreign areas, and that the sciences of man should not be left out of consideration in such relations. To illustrate this point we have directed attention to South America and to the least developed portion of the continent, the tropical lowland area.

BOOKS ON SCIENCE FOR LAYMEN

ARE WE COMING OR GOING?[1, 2]

READING one of Professor Hooton's recent books is like panning for gold—with the exception that Hooton does the "panning," and it is the reader who must search for a few grains of gold or, mayhap, even a nugget or two. The two books above listed are quite similar in content and in theme. The 1939 volume is a collection of sundry Harvard Alumni Club luncheon talks; the 1940 volume an extension of the five Vanuxem Lectures at Princeton. There is in each an outline of human evolution, a discussion of human races, and a general viewing-with-alarm and pointing-with-scorn. The 1940 volume adds a discussion of infra-human Primate behavior and human body types.

Any thinking person who scans the world scene to-day and who reads the record of twentieth century history, will agree with Professor Hooton that something's wrong, that man has made a mess of his social structure.

It is in the diagnosis of basic causes that the author strikes out vigorously. He is convinced that man's "biological inferiority"—the culmination of an evolutionary process accelerated and accentuated by civilization—is at the root of all criminal behavior and all social inadequacies. In the conflict between biological determinism *vs.* social opportunism Hooton backs the former, regards the latter as an "also ran." In charging that medicine and social science have neglected human biology and human heredity in favor of environmental conditioning he goes to the other extreme and virtually neglects environment. This may be no more than the shock psychology of over-exaggeration, to stimulate the physician and the social scientist to meet the bio-anthropologist at least half-way. The pendulum, swinging free, goes to extremes, but it soon gravitates to a balance. At the moment Hooton has the pendulum in biological imbalance, as it were.

Man is biological, but he also is a social being. His biological make-up must inevitably condition his social pattern; but likewise is it true—whether equally true or not, we'll not say—that the totality of his environment must shape the expression of his biological constitution.

The statement that criminal behavior is associated with a given physical type ("mosaic" of morphological traits) pays too little attention to the social aspect of the definition of what constitutes a crime. During Prohibition it was a crime to possess liquor; now it is not. Yet many of us, no different physically now than then, were "criminals" every time we partook of some liquor "just off the boat!" Man defines the crime, not crime the man, and criminal opportunity bulks at least as large as the criminal's physique. We are products of time, yes, but time may be measured in the social set-up of the moment.

Professor Hooton outlines an aggressive program for the study of man's constitution. In forceful and often witty style he points out man's shortcomings and suggests a program—largely eugenical—for setting things right. His is the biological approach. It must be complemented by a program of social integration. A concerted biologico-social study of man is now indicated—not merely a questionnaire type of social program in august dignity or a statistical and morphological investigation in aloof solitude. Teamwork is the answer!

W. M. KROGMAN

[1] *Twilight of Man.* E. A. Hooton. Illustrated. x + 308 pp. $3.00. 1939. Putnam.

[2] *Why Men Behave Like Apes and Vice Versa.* E. A. Hooton. 1940. Princeton University Press.

UP FROM THE ALGAE[1]

For forty-five years Campbell's "Mosses and Ferns" has been the standard text for the morphology of these groups. Now in his eightieth year the author carries to completion his great project of dealing with the morphology of all vascular plants.

The obvious popular appeal of the title is not quite borne out by the contents and could not be because no one can yet map the evolution of the higher plants, for "It is not expected that all the conclusions presented by the writer will meet with general approval but it is hoped that they may direct attention to much-needed investigation of many disputed points in the classification of embryophytes which is at present in need of thorough revision." Read in the spirit of this sentiment the book is an extremely valuable contribution. It really consists of a compendium of present-day information on the structure and development of plants from mosses to flowering plants, together with as much of the theoretical evolutionary path over which they have traveled, as may be made out at the present time.

The first section of the book on the Bryophytes looks familiar to a student of the earlier "Mosses and Ferns." But in the later sections the progress of science, especially in the discovery and interpretation of fossils gives the book an aspect which could never have been anticipated by the student of 1895.

The first of these discoveries came with the gradual realization by a number of different workers, in the next decade, that the "fern leaves" so abundant in the coal measures were seed plants (Pteridosperms) not related to the ferns at all.

A second major change was introduced by the discovery of Kidston and Lang in 1921 in the Devonian rocks of Scotland of curious vascular plants which partook of the character of Thallophytes, Bryophytes and Pteridophytes, but could not at first be assigned to any of these. They were slight upright plants with conducting tissues as in the higher plants but without differentiation into any of their organs, *i.e.*, leaf, root or stem. These plants, Rhynia and Hornea, are now considered a primitive type of Pteridophyte, but in reaching this conclusion ideas of phylogeny of the higher plants had to be pretty thoroughly revised.

The third revolutionary discovery during the half century covered by Campbell's studies was Wieland's elucidation of the detailed structure of fossil cycads in 1906. This work demonstrated the distinctness of fossil cycads (Bennetitales) from their living relatives and furnished the data from which Parkin and Arber elaborated what is by many regarded as the best theory for the origin of angiosperms. On this theory the conelike flowers of magnolias are regarded as primitive. Later Bessey and others built systems of classification (and they believed of the phylogeny) of the flowering plants, starting from Magnolias and Buttercups.

Campbell rejects these newer ideas of the origin of flowering plants, deciding (rightly) that the evidence supporting them is inconclusive, and takes up the system of Wettstein, which regards the amentiferous oaks and walnuts as primitive and derives most of the other flowering plants from ancestors of this general type. With this, as Campbell recognizes, many will disagree. For while it appears to accord better than Bessey's system with the earliest angiosperms we know as fossils, it fails to connect with any particular gymnosperm type which can be regarded as ancestral.

The adherents of the opposing theory maintain that the earliest angiosperm

[1] *The Evolution of Land Plants.* D. H. Campbell. Illustrated. 731 pp. $6.50. 1940. Stanford University Press.

floras known to us represent a great advance beyond what the first (unknown) angiosperms must have been. Thus one of the earliest of certainly identifiable angiosperms (early Cretaceous) is the Sycamore, Platanus; and concerning this Seward[2] remarks: "This forest tree exhibits no features which stamp it as a primitive type or as one of the earliest members of an evolutionary series." In the upper Cretaceous, moreover, there were about 70 families of angiosperms, covering almost all types, from the lowest to the highest.

Thus the origin of the angiosperm remains the chief problem of plant phylogeny. Campbell by summarizing existing knowledge has in effect clearly stated the problem and so should facilitate its solution. The book is one which will be used constantly everywhere plant morphology is studied.

ROBERT F. GRIGGS

FACT GATHERING[1]

HISTORICALLY the oldest and, from a purely factual standpoint, the most basic, phase of biological science—the description and classification of the forms of life, the classical field of taxonomy, has been accused, and with reason, of contributing but little to the ever-changing facies of the main currents of biological thought. The essential value of its work in the gathering of facts for the record to be consulted by workers in other fields has never been questioned, but until very recently systematics was looked upon as without much general interest or even application to other branches of biology. However, with the vast advance in purely systematic knowledge and particularly with the great increase in detailed data on certain groups, it has now become possible for the specialist in other lines to check his theories and more accurately formulate his questions, to find material for new paths of experimental departure and to build up new chains of inductive reasoning from the once neglected, and even scorned, field of taxonomy. Not only do the data of systematics thereby cast a correcting and directing influence upon the philosophical background of current work in genetics, cytology, embryology, ecology and other specialties, but also the impact on these data of minds trained along other than taxonomic lines has tended to mold purely systematic work as well. It is therefore at a most propitious time for biologists that a book dealing with the "new" systematics makes its appearance.

This book is issued under the sponsorship of the Association for the Study of Systematics in relation to General Biology under the editorship of Julian Huxley. Besides a valuable introduction by the editor, it contains twenty-one chapters, each with a different authorship, and, fortunately, each with a useful literature list. All that can be done in the limited space at the disposal of the reviewer is to list some of the chapter titles, in the hope that they may stimulate the reader of this review to go over the book itself. Mutations and Geographical Variation is discussed by Timofeeff-Ressovsky; Taxonomic Species and Genetic Systema by Darlington; Bearings of the "Drosophila" Work on Systematics comes from the pen of H. J. Muller; Hogben writes of Problems of the Origin of Species; de Beer on Embryology and Taxonomy; Calman presents A Museum Zoologists' View of Taxonomy; and Ford gives an account of Polymorphism and Taxonomy.

All the chapters are full of interest and appear to result from much careful deliberation and reflection. The text, on the whole, is free from typographical error, but occasional mistakes have

[2] A. C. Seward, *Plant Life through the Ages*, p. 298.

[1] *The New Systematics*. Edited by Julian Huxley. Illustrated. viii + 583 pp. $6.00. July, 1940. Oxford University Press.

eluded the proofreader, such as, on page 7, where Darwin's book is referred to as "Animals of the Variation and Plants under Domestication" instead of "The Variation of Animals and Plants under Domestication." Two good indices, one of names, and one of subjects, make readily available the contents of a book well worth the attention of biologists of all specialties.

H. FRIEDMANN

IS LIFE A MIRACLE?[1]

THE task of surveying the information we possess concerning animal and plant life is one to be approached with considerable deliberation. The selection of what to give and what to leave out is obviously one of the most difficult to make. Even when the authors have pleased themselves with the reasonableness of the approach and the material submitted, there still remains the very strong probability that few others will agree with them.

This volume is a compilation of chapters by six authors. It begins with the dawn of life, proceeds through the various phases of evolution and then turns its attention to the animal kingdom. There is no attempt to become involved in the intricacies of classification. The speed with which the invertebrates are dispatched is amazing. The emphasis rather falls around the discussion of various topics such as animal courtship, how animals make a home, modes of travel and the like. The plant kingdom finds itself in between the earlier animal evolution and animal kingdom sections and the large later section on various phases of the biology of man. This concession to any plant miracle again is built around topics like plant anatomy, plants in relation to man and plant breeding. The book then proceeds to devote nearly half of its pages to the story of the human family tree, the races of mankind, human physiology, human psychology and a brief review of some great men in medical history.

[1] *The Miracle of Life.* Edited by H. Wheeler. 480 pp. Halcyon House.

This book is written for the general reader. "The Miracle of Life" has been condensed into 480 pages, with over 500 illustrations taking approximately one third of the page space. The pictures are adequate but poorly printed. The text is sketchy and brief. It further is a distinctly British volume which relies pretty much upon a background of the British Isles. The wrapper informs us that it tells "what modern science knows about all living things: Birth, Growth, Heredity, Instinct, Reproduction, Etc." With that emphasis upon birth and reproduction it is a revelation, if not a minor miracle, to find the phenomena in man are covered in three pages without any pictures whatsoever of the reproductive apparatus. This volume surely will not offend the most conservative home of even thirty years ago.

To the person with a biological background this volume is elementary to the extreme, and will receive merely an examination of its pictures. Our readers of *Science* will be delighted to learn that the deer bot fly still travels over eight hundred miles an hour. No one will dispute the miraculous nature of this myth.

In spite of its weaknesses, it is a volume that is full of information in readable form. The pictures are its chief source of attraction, and may insure that some of the text will be perused. For one who knows little about biology, here is a good place to begin. It is in no sense a technical book, and will find a place in a personal library of a general nature. It surely will acquaint the general public with a mass of biological knowledge.

IRA B. HANSEN

OLIVER LODGE

THE PROGRESS OF SCIENCE

SIR OLIVER LODGE, 1851–1940

To the "man in the street," the typical professor of natural philosophy is a man of dignified bearing with strongly developed features, a man having the appearance occasionally of being lost in the clouds while peering into the mysteries of the universe, a man, nevertheless, of great action and energy, a man fearless in the cause of his convictions, a man able on occasion to stir the multitude with the profundities of his learning, yet one humble in himself, and the faithful servant of his Creator. Few typify this conventional ideal as did Sir Oliver Lodge. To the layman, he was probably better known than any other living man of science, a fact for which his strong personality was largely responsible, enhanced as it was by a clarity and simplicity in writing and speaking which enabled his hearers to understand the message, and to become incited to enthusiasm for it.

A product of the school of classical physics and of the era in which the science of electrodynamics was born, Lodge was a firm believer in the reality of things; and while open to conviction in respect of the new, he sought always to cement it to the fabric of the old. The aether in his eyes was a very real medium. Its equations to him were the servants of its substance, and he had little sympathy with the kind of substance which had no parentage other than in the equations. He was one of those pioneer experimenters who, seeking to make the aether declare itself in all its actions where moving bodies are concerned, evolved a series of results which, unassailable in accuracy, were yet inconsistent with each other in the spirit of thought of the day and which, in the hands of the more venturesome Einstein, led through the intermediary work of Larmor and Lorentz to the concept of the theory of relativity.

Enthused with the revelations of the work of Faraday and Maxwell, Lodge's first important investigations had to do with lightning rods and the general subject of electrical oscillations. As a by-product of this work, he was responsible for the invention of a method of dispersing fog. He almost anticipated the work of Hertz on electrical oscillations. He invented the "coherer" and was the first to transmit wireless messages over considerable distances. It is probable that had his knowledge of the science of electricity and magnetism been less he would have been encouraged to pursue these investigations into that realm of practical wireless telegraphy whose successful realization fell to the fortune of others in later years. The fact is that in terms of the knowledge of those times, a realization of transmission of electrical signals over a distance comparable with the earth's radius seemed a fantastic impossibility. Indeed, it is ony the more recent discoveries of the existence of special conditions in the upper atmosphere, and associated with the Kennerly-Heavisidean Layer, that have enabled experiment to be crowned by theory with "common sense."

Oliver Joseph Lodge was born on June 12, 1851, at Penkhull, near Stoke-on-Trent, England, and received his early education at Newport Grammar School. He received much of his early advanced education in physics at University College, London, and obtained the degree of doctor of science in 1887. Following a lectureship on physics at Bedford College for Women, he was appointed assistant professor at University College, and in 1881 he was elected first professor of physics at Liverpool. In 1900 he was

appointed principal of the new university at Birmingham, which position he held until 1919. In 1877 he married Mary, the daughter of Alexander Marshall, and his family comprised six sons and six daughters.

Lodge is the author of several books, such as "Elementary Mechanics," "Modern Views of Electricity," "Pioneers of Science," "The Ether of Space," which have been a source of inspiration to countless physicists and doubtless have inspired many of them to specialize in the field of electrodynamics. In addition, he is noted for his writings upon matters pertaining to psychical research, to which subject he gave considerable attention during the latter portion of his life. In this realm, while he was probably the most outspoken of his contemporaries, he was not alone, for Sir William Crookes, Lord Rayleigh and indeed Sir J. J. Thomson, also, viewed these matters as worthy of consideration.

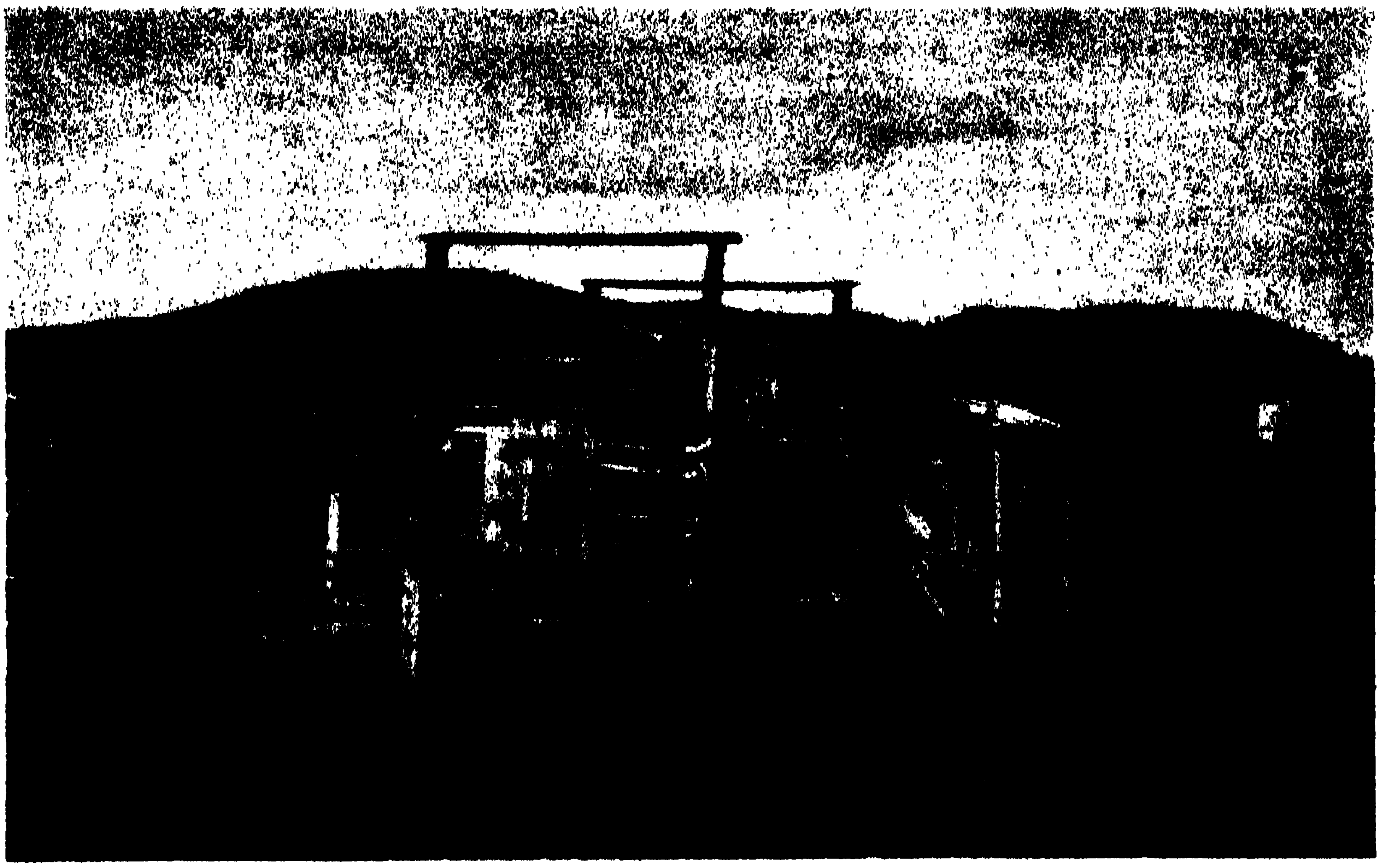
Sir Oliver Lodge was always a striking figure in any assembly of men of science; but in spite of his dominating personality, he was a man of kindly sympathy and was greatly helpful in his encouragement of others. He was, indeed, an ornament to science and a lovable link between the physics of to-day and that of the era which is past.

W. F. G. SWANN

INVESTIGATIONS AMONG THE CARRIER INDIANS OF BRITISH COLUMBIA

THE Carrier Indians in the vicinity of Stuart Lake, British Columbia, were visited during the summer of 1940 in order to study certain problems of the relationship of primitive economics to social and political organization. The Carrier are exceptionally suitable for a study of this kind because several marked changes in the framework of their socio-political organization during

CARRIER FISHERMEN STILL USE DUGOUT CANOES
ON STUART LAKE, WHICH ARE OFTEN POWERED BY OUTBOARD MOTORS.

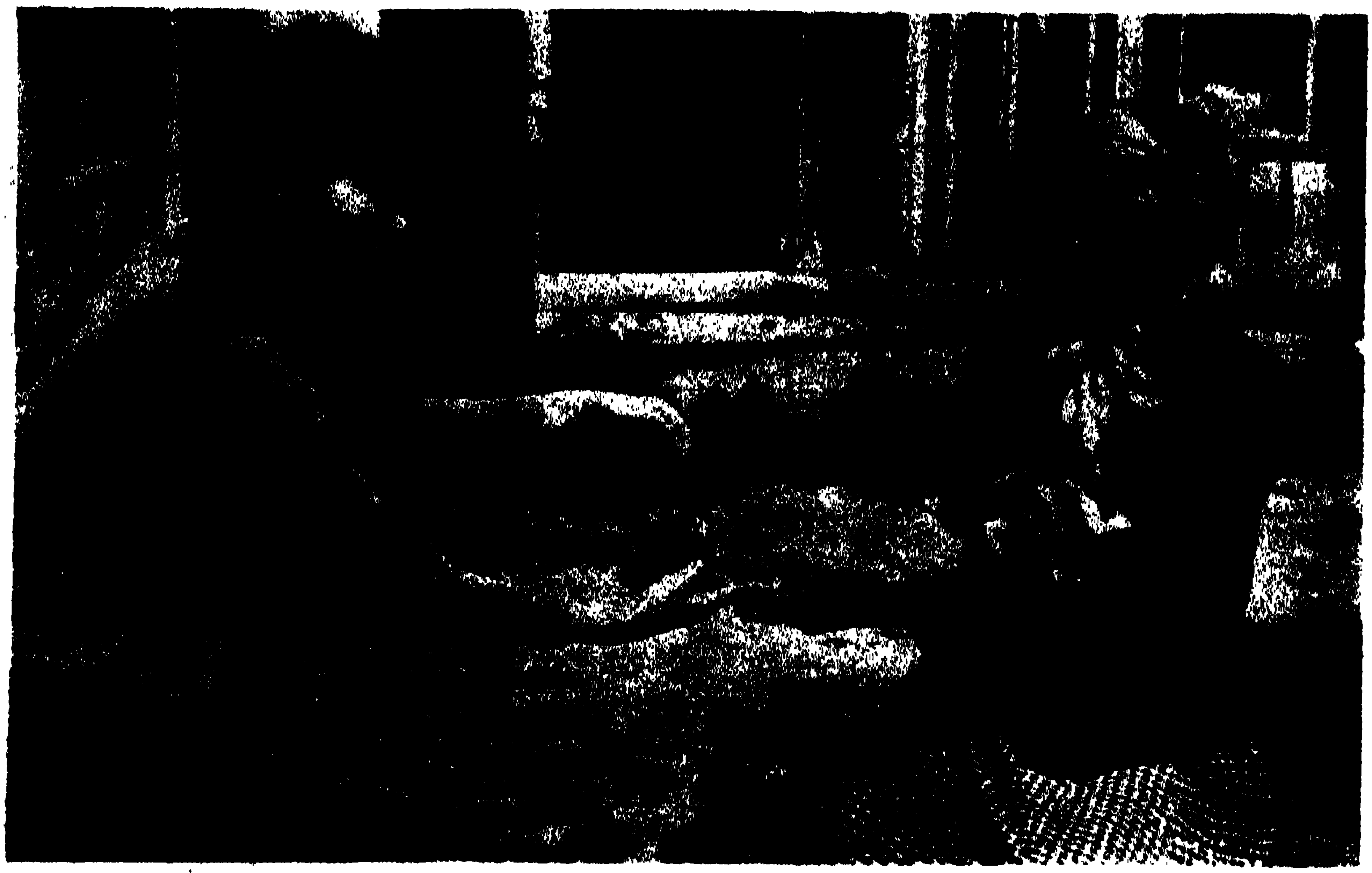


MODERN CARRIER FOOD CACHES ARE BUILT OF LOGS

the prehistoric period can be reconstructed and because the impact of European culture on their own during the historic period has been more orderly and less devastating than among most Indian tribes.

The Carrier inhabit a vast territory between the Rocky Mountains and the coastal ranges of British Columbia. In subsistence terms, they occupy a region where the hunting and fur trapping area of the great Canadian interior and the salmon area of the Northwest Coast overlap. Game and fur-bearing animals killed in the extensive forests and fish caught in the headwaters of the Fraser and Skeena Rivers have always contributed about equally to Carrier existence. To-day, most Carrier Indians have exclusive rights to trap-lines which are registered with the government of British Columbia. These registered trap-lines permitted a somewhat novel and fruitful field technique. Starting with maps of present-day holdings, the succession of land ownership was traced back through five generations and concomitant changes in social and political usages recorded. Earlier changes were reconstructed by comparative ethnography. Three main stages of Carrier development were reconstructed.

At one time the Carrier, like the other Athabaskan tribes of the interior of Canada, lacked clans and a hereditary aristocracy of wealth. Land was probably held and exploited communally by bands in which all people were substantially equal. But in comparatively recent prehistoric times matrilineal clans and a potlatch system spread up the Skeena River from the Tsimshian Indians and were introduced first to the Babine Lake Carrier, later to the Stuart Lake Carrier. Tracts of land came to be held by "nobles," who gave potlatch feasts to support their titles and who inherited both land and titles matrilineally, within clans, from their mothers' brothers. The mechanics by which this new type of land tenure and use were substituted for the old system can not be known in detail. Two features of the older Carrier culture, however,



DEMONSTRATION OF NATIVE METHOD OF WEAVING FISH NETS

DOGS ARE TRAINED TO CARRY LOADS OF AS MUCH AS FORTY POUNDS

probably facilitated its adoption: Cross-cousin marriage and bride service. If it had been customary that a man marry his mother's brother's daughter and go to live at her house for several years before and after his marriage, the introduction of the new system meant merely that he would inherit his father-in-law's, that is, his mother's brother's titles and property and that his children would belong to his wife's clan.

By the time the white man arrived in Carrier country, achievement of status by wealth had become a dominant theme in Carrier culture. A somewhat greater wealth made possible by the white man's superior technology—steel traps, guns, axes, and so forth—at first intensified the old system. Potlatches involved bigger feasts and a greater quantity and variety of goods to distribute to rival nobles. But eventually, other influences from the white man began to undermine the native institutions. The Catholic Church banned cousin marriage and discouraged potlatching. A desire to keep rather than to distribute wealth and increasing importance of individual ownership and of patrilineal inheritance of land caused more and more nobles to divide their estates among their own sons in defiance of the ancient obligation to give it and the potlatch title it supported to their nephews. Registrations of traplines was the final factor that entrenched the new system. To-day, therefore, although the Carrier continue to live mainly by trapping and fishing, their socio-economic unit is the individual family.

Thus, the Stuart Lake Carrier changed from a band organization to a clan-potlatch system and later to a family system without any important modification in the pattern of their economic activities.

A CARRIER WOMAN
DEMONSTRATING THE USE OF ABORIGINAL CARRYING NET AND TUMPLINE.

These changes, therefore, were caused by the external influence of ideologies, a purely historical phenomenon, and not by any kind of "economic determinism."

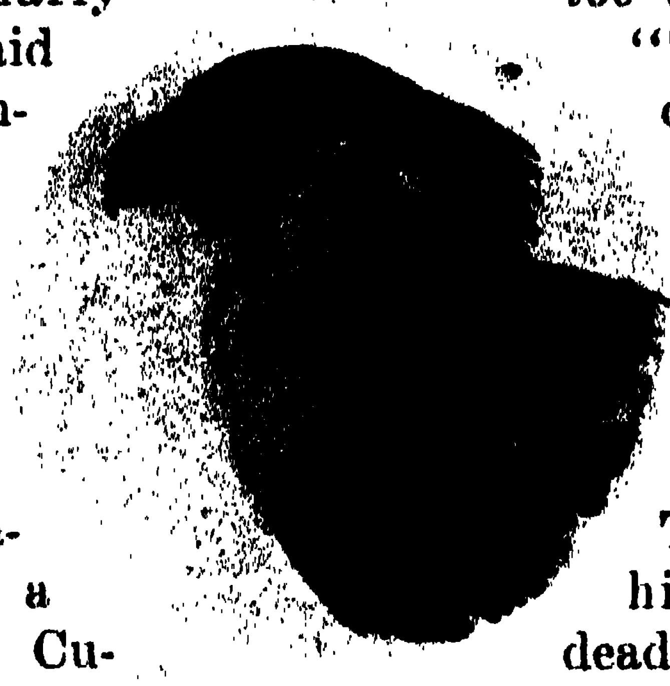
JULIAN H. STEWARD

EXPEDITION TO STUDY MEXICAN BIRDS

GEORGE MIKSCH SUTTON, Cornell University's curator of birds, and Olin Sewall Pettingill, Jr., zoology professor at Carleton College, led an expedition to the hill country of southwestern Tamaulipas in February to study birds during the breeding season from February to June. With Sutton will be big sheets of paper and a complete water-color outfit for a series of bird paintings. With Pettingill will be cameras and color film. The expedition will center on a pictorial conquest of the birds of the Sabinas Valley and of the mountains west of the village of Gomez Farias.

Headquarters probably will be the Rancho Rinconada, a spot known to Sutton, who worked the Sabinas Valley

briefly in the spring of 1938. The expedition plans to be in Mexico for several weeks so that the ornithologists may obtain data on the wintering bird-life, the transient forms and the courtship, nesting activities and territorialism of the breeding species.



"The region is particularly rich in tropical birds," said Professor Sutton, in commenting on his work in 1938. "Near the Rancho Rinconada we encountered five species of Parrots—the Military Macaw, Red-crowned and Yellow-headed Parrots, Green Parakeet, and Aztec Parakeet; a tinamou; the great-crested Curassow that is known as the *Faisano Real* or 'Royal Pheasant'; the wild Muscovy Duck, and numerous brightly colored small birds, including tanagers, warblers, hummingbirds and buntings. Several kinds of hawks breed in the vicinity, including the little known Crane-legged Hawk, *Geranospiza nigra;* the handsome Mexican Goshawk; the Black Hawk; a middle-sized hawk that is the counterpart of our United States Broad-wing; the trim Bat Falcon; and a long-tailed, bird-eating species known as the Collared Micrastur. Vultures and Caracaras are common, of course, these being the garbage-disposal system of the country-side."

The worst difficulties the ornithologists will encounter will be dysentery and ticks. The ticks, which are variously known as *nighuas,* *pinelillos, conchudas, grapatas* and *airedores* (whatever the etymology of these words may be!) are very bad in spring. In 1938 Sutton's party had a time with them, finding such items as sulfur, gasoline, kerosene, carbide and alcohol of no use in combatting them. "The *pinelillos* were worst," said Sutton. "They were very small, got onto us by the hundred, and had to be scraped off with knives. But we never had any serious trouble as a result of them." As for snakes, they apparently are rare about the Rancho. The only snakes Sutton and his party saw in 1938 were dead ones along the highway or partly eaten ones that were being carried about by hawks; and none was a rattlesnake.

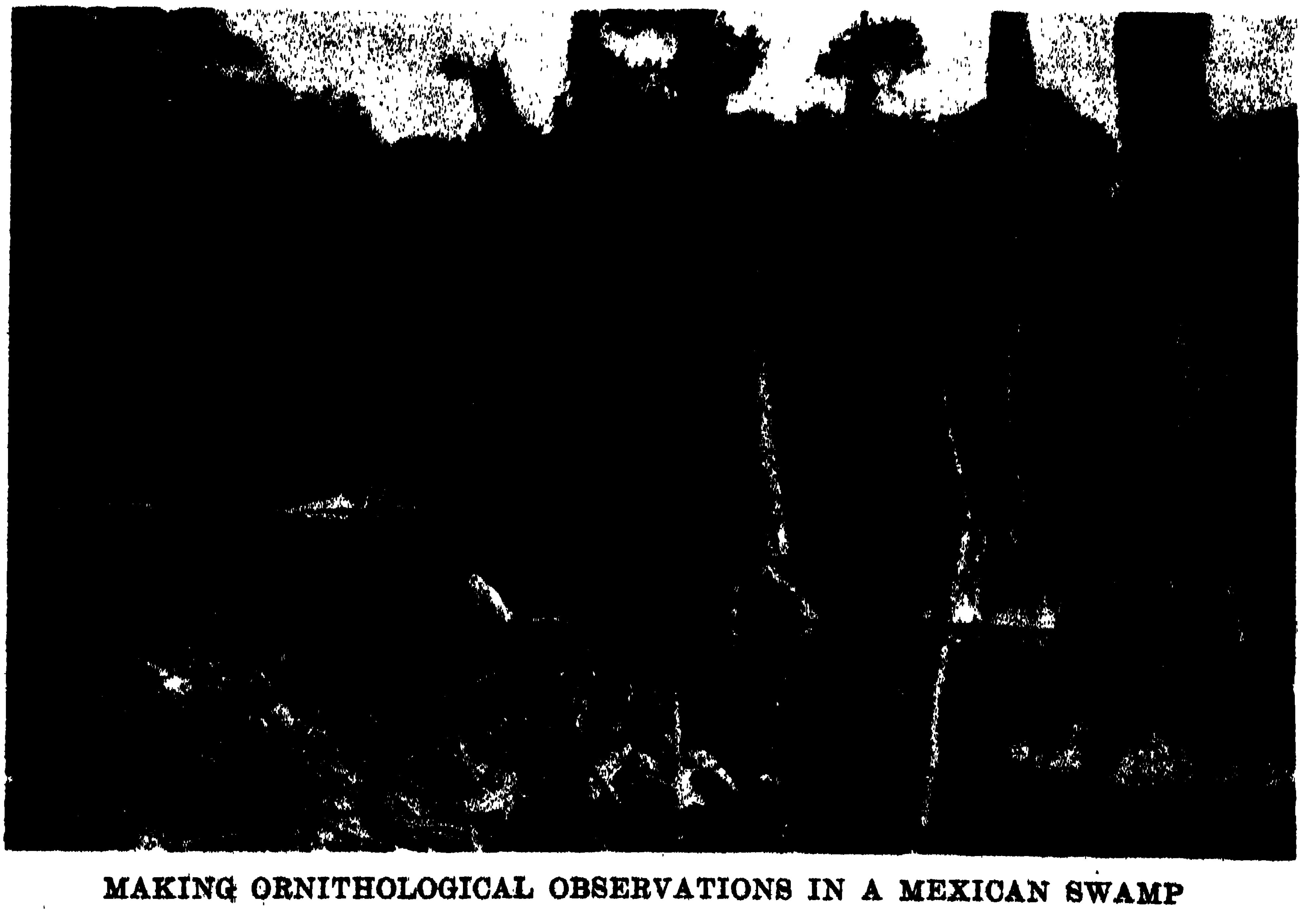
Sutton's first collection of Mexican bird paintings (a series of sixty heads made direct from life or from freshly killed specimens) was displayed at the International Ornithological Congress at Rouen and Paris, France, in 1938, one of them (that of a Coppery-tailed Trogon) being reproduced in full color in the Proceedings of the Congress and in the French ornithological magazine *L'Oiseau.* Most of them have since been displayed at meetings of the Wilson Ornithological Club, and at a one-man show at the American Museum of Natural History in New York City. Reports on Sutton's 1938 and 1939 bird-work in Mexico have been appearing in *The Auk, The Condor,* the *Wilson Bulletin* and the *Annals* of the Carnegie Museum of Pittsburgh. He has prepared a semi-popular book on his 1938 work, but this is not yet ready for publication.

Sutton and Pettingill are old teammates, both of them having participated in the memorable hunt for the Harris's

NOTE: The two bird heads reproduced on this page were sketched by George M. Sutton. The first one is Audubon's Caracara, a common Mexican bird sometimes called the "Mexican Eagle," sketched from a freshly killed specimen by George M. Sutton; the second is the Curassow, known as the "Faisano Real" or "Royal Pheasant," painted from a male specimen. The knob at the base of the bill is bright yellow.

A BAT FALCON
THIS SPECIES NESTS ON THE RANCH RINCONADA, NEAR THE EXPEDITION'S HEADQUARTERS.

COPPERY-TAILED TROGON
ONE OF MEXICO'S HANDSOMEST BIRDS, KNOWN AS THE "QUA" OR THE "FLAG BIRD."



MAKING ORNITHOLOGICAL OBSERVATIONS IN A MEXICAN SWAMP

TICK BITES
ON THE LEGS OF A MEMBER OF THE EXPEDITION AT THE RANCHO RINCONADA.

Sparrow's nest at Churchill, Manitoba, in 1931. They were graduate students at Cornell together in the early '30's, and are, respectively, first vice-president and secretary of the Wilson Ornithological Club. Sutton, who is a fellow of the American Ornithologists' Union, is author of the books "Eskimo Year" and "Birds in the Wilderness" and illustrator of many bird-books, including W. E. Clyde Todd's recently published "Birds of Western Pennsylvania." Pettingill, one of the outstanding bird photographers of the country, has contributed to such magazines as *Natural History*, *National Geographic* and *Bird-Lore*.

Other members of the expedition will probably be Dwain W. Warner, one of Dr. Sutton's graduate students at Cornell, and Robert B. Lea, one of Pettingill's students at Carleton. M. S. P.

AN AUTOMATIC DRIVE FOR THE SCHMIDT TELESCOPE ON PALOMAR MOUNTAIN

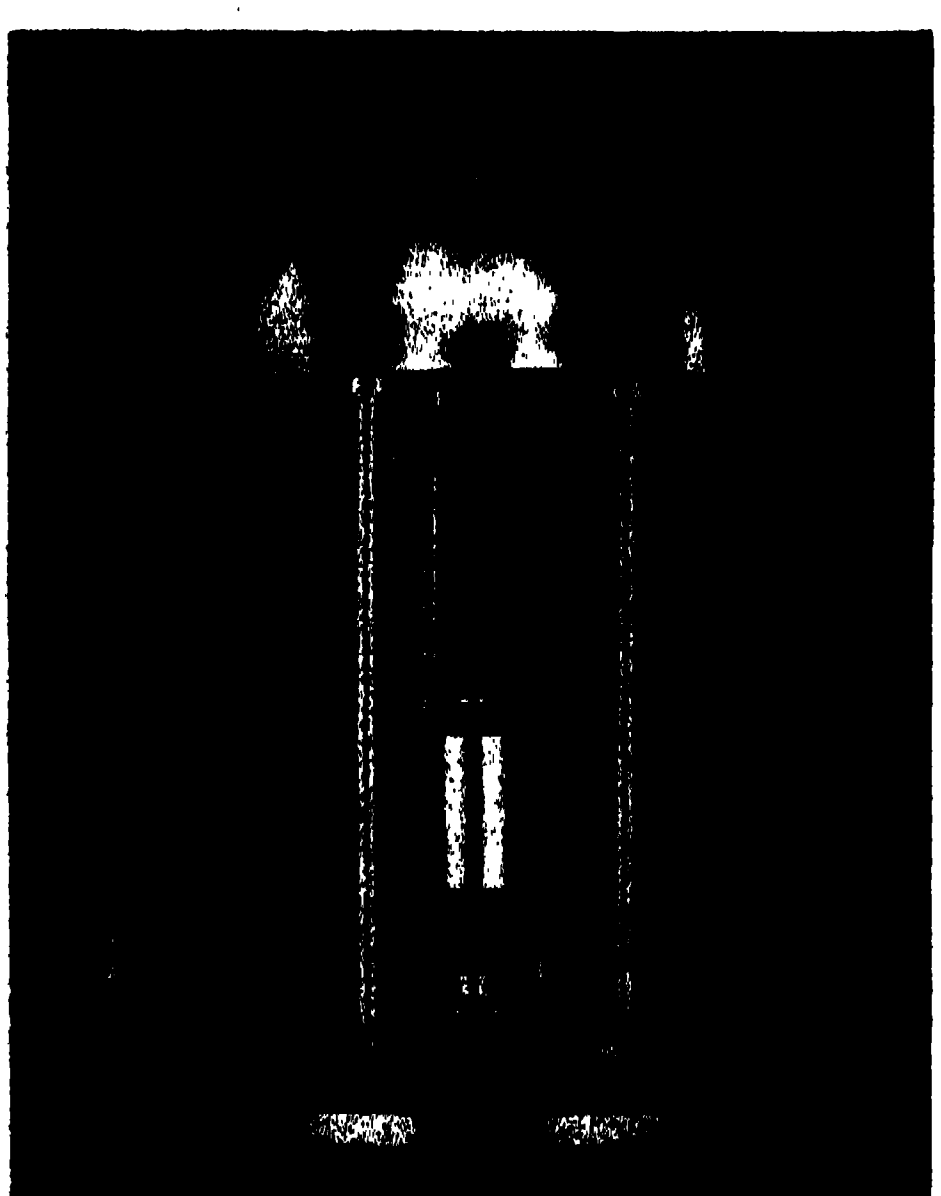


FIG. 1. VIBRATOR UNIT
OF TIME STANDARD. DIAMETER OF BASE, 14 INCHES.

DURING the intensive search for supernovae which was conducted with the Schmidt telescope on Palomar Mountain, much time was wasted in manually guiding the telescope. It therefore became desirable to install an automatic drive which would enable us to eliminate manual guiding for exposure times up to thirty minutes.

The new drive, now in use, consists of a synchronous motor supplied with power from a precise, adjustable frequency time standard. The frequency of the standard is varied from sidereal rate by a calibrated amount to compensate for the effect of atmospheric refraction and the fact that in practice the polar axis of the telescope is pointed to the apparent pole rather than to the true pole.

The time standard,[1] shown in the ac-

[1] A complete description of this time standard is given by the inventor, Henry E. Warren, in *A.I.E.E. Transactions*, March, 1940.

companying photograph, consists of a vertical wire tensioned by a weight, and is kept in transverse vibration at its fundamental frequency. A small bar magnet attached to the midpoint of the wire is coupled with pick-up and feed-back coils, these coils being connected to a simple vacuum tube circuit which maintains the wire in vibration.

By proper choice of the dimensions and materials of the upper and lower halves of the wire, the frequency of vibration is made substantially independent of the temperature. Also by use of a bow spring coupling between the wire and the tensioning weight, the frequency is made substantially independent of variations in the amplitude of the vibration. The unit in use at this telescope has the tensioning weight adjusted to produce a frequency of vibration of 60 cycles per sidereal second. The precision of the time standard is about one tenth of a second per day.

The lower portion of the tensioning weight consists of a cylindrical Alnico magnet, in the air gap of which is a coil of fine wire. Flow through the coil of measured direct current of proper sign and magnitude causes a downward or upward force on the weight, causing in turn a definite increase or decrease in frequency. The current to this frequency adjusting coil is set to the proper value by means of a rheostat, as indicated by a milliammeter calibrated directly in "seconds of arc per hour" deviation from sidereal rate. The rate deviation is read from a chart, giving its values for various declinations and hour angles.

Although a drive of the type described should, in all directions in the sky for which the differential refraction does not become too great, allow us, without manual guiding, to obtain images which do not exceed the limiting size of photographic point images (about 30 μ), prac-

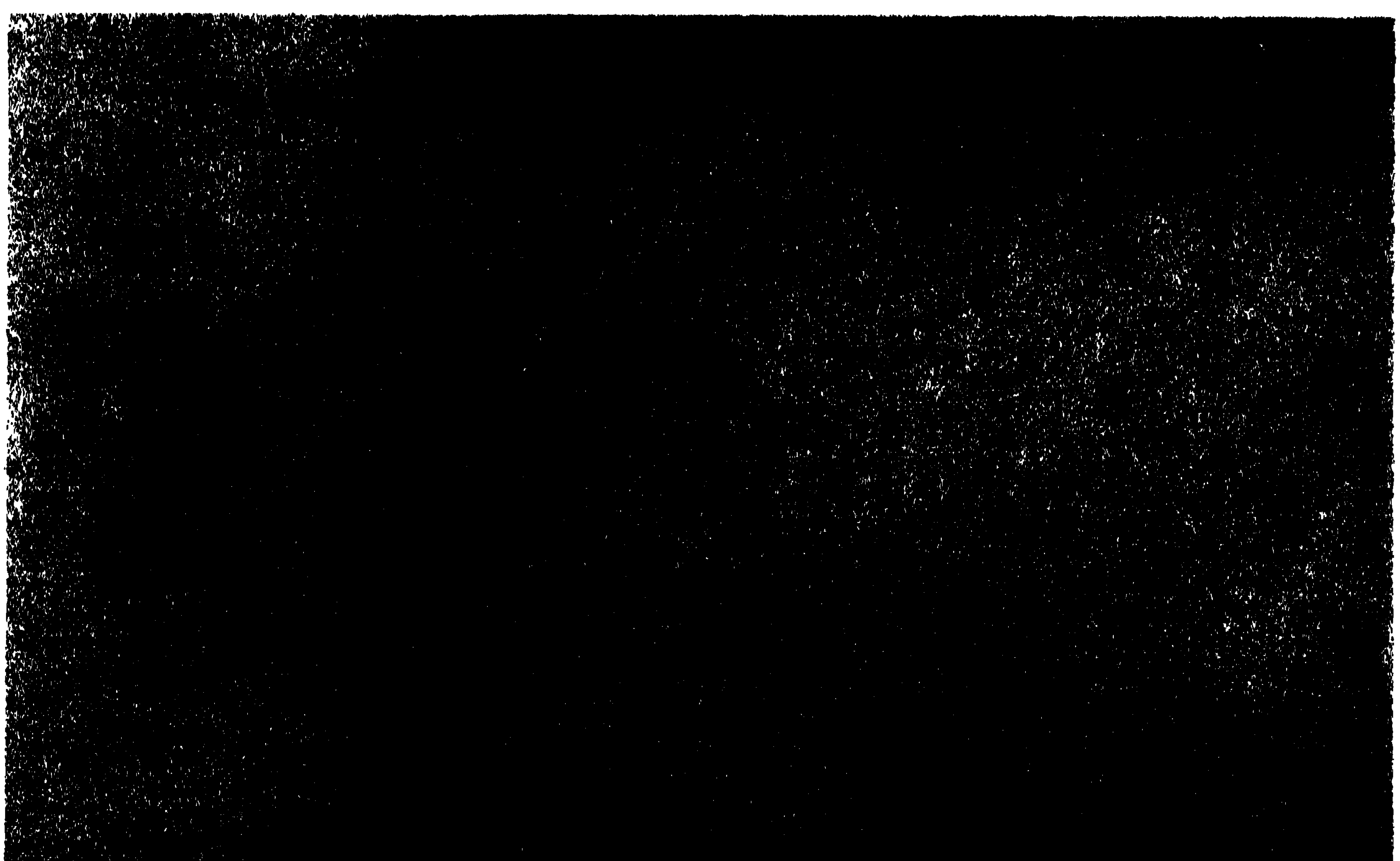


FIG. 2. STAR PHOTOGRAPH WITH NEW SCHMIDT TELESCOPE

DURING THE 30-MINUTE EXPOSURE THE TELESCOPE FOLLOWED THE STARS IN THEIR DIURNAL MOTIONS AND CORRECTED FOR THEIR APPARENT DISPLACEMENTS PRODUCED BY REFRACTION OF THE ATMOSPHERE, ENTIRELY BY AUTOMATIC CONTROL DESCRIBED IN THE TEXT.

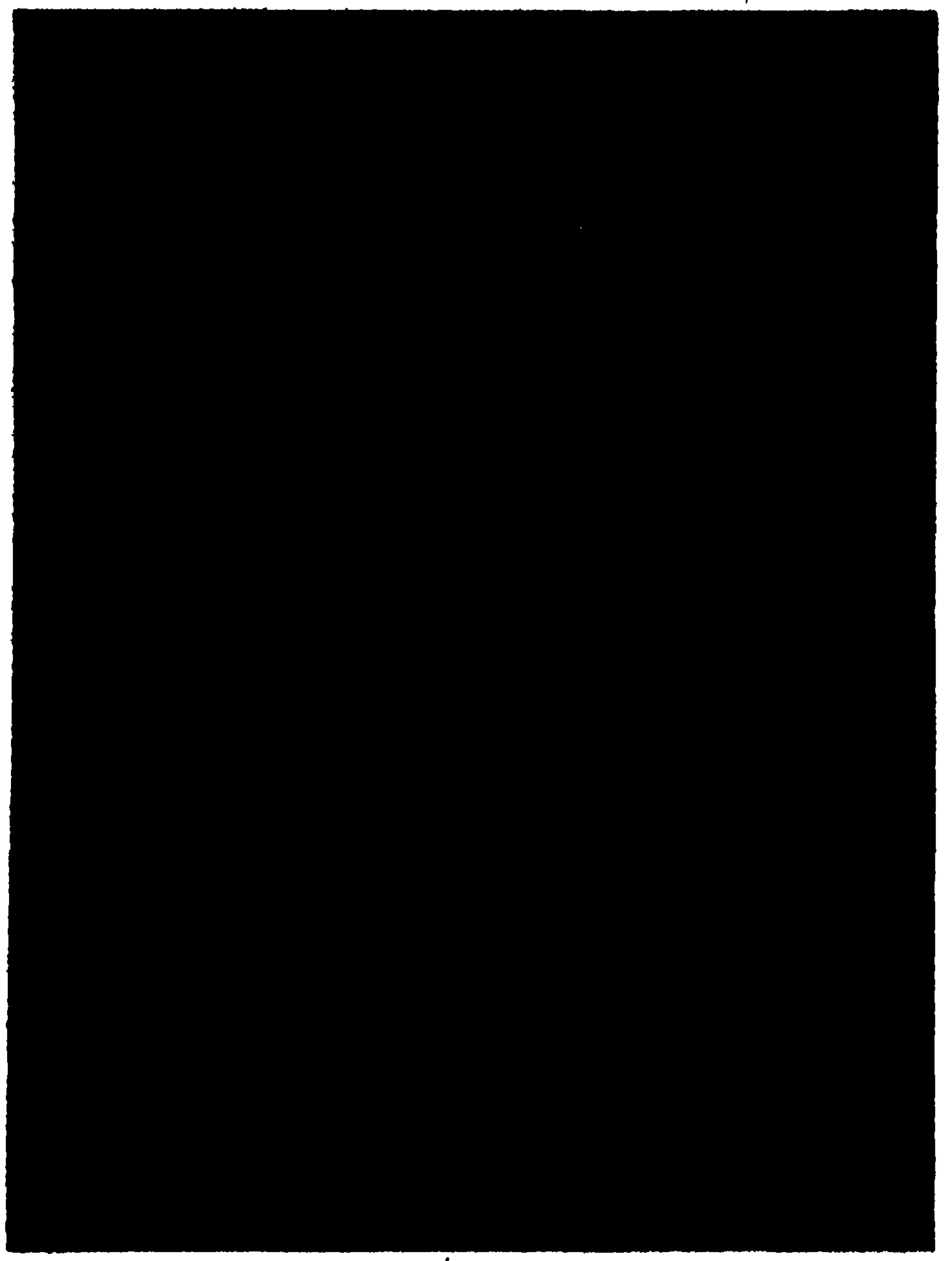


FIG. 3. STAR AND METEOR SPECTRA
ANOTHER DIRECT PHOTOGRAPH OF A REGION OF THE SKY WITH THE TELESCOPE GUIDED AS BEFORE, IN WHICH THE STAR-IMAGES ARE SPREAD OUT INTO SPECTRA BY A FULL-SIZED PRISM MOUNTED IN FRONT OF THE TELESCOPE. THE LONG, BRIGHT DIAGONAL TRACE IS DUE TO A BRIGHT METEOR THAT FLASHED ACROSS THE FIELD DURING THE 40-MINUTE EXPOSURE.

tical errors are introduced because of the mechanical imperfections of the gear train which couples the telescope tube with the driving motor. The deviations of the drive were determined by observations of the excursions of a star from the cross hair in the guide telescope attached to the main tube. A 24-hour plot (in five-minute intervals) revealed the existence of a periodic error of 8 seconds of arc $\times \sin\ (2\pi t/T + \alpha)$, where, if the time, t, is measured in minutes, we have $T = 24$ minutes, plus some additional small and irregular errors. A potentiometer driven from the telescope gearing gives a sinusoidally varying voltage of proper magnitude, period and phase, such that, when this voltage is impressed across the rate-adjusting coil of the time standard, the periodic error is essentially removed by alternately driving slower and faster than the normal rate.

For routine exposures of 30-minute duration, the procedure has been to set the telescope at the desired position for taking the photograph, set the rate dial at the proper value, start the film exposure, leave the telescope for the exposure period and return only to close the shutter and to change plates. It is now possible for one person to take photographs practically continually and yet have all the plates developed, marked and partially examined by the end of the night. This speeding up of the work with Schmidt telescopes should prove particularly effective for programs such as the search for supernovae and common novae, whose early discovery is of importance.

In Figs. 2 and 3 are reproduced enlarged sections of films which were obtained with the 18-inch Schmidt telescope driven entirely automatically. The direct photograph in Fig. 2 shows that the diameters of the images of the faintest stars are only slightly larger than 30 μ which is approximately the diameter of the limiting photographic image. Fig. 3 is the enlarged reproduction of an objective prism photograph obtained during a 40-minute exposure which was guided entirely automatically. Both the slight increase in the size of the images in Fig. 2 and the slight widening of the spectra in Fig. 3 are due to the small irregular differences between the motion of the telescope tube and the motion of the stars, differences which still remain after the average rate of driving is set correctly and the fundamental periodic error of the worm gear is automatically compensated for.

For the classification of spectral types of stars unwidened spectra as those shown in Fig. 3 are not suitable because of the difficulty of identifying enough spectral lines. The spectra may con-

veniently be widened with the automatic drive by setting its rate slightly off from the correct rate.

For some purposes, such as the determination of the magnitudes and colour indices of faint stars, very perfect images are needed for the production of which our automatic drive is not quite accurate enough. Also, the work with some of the filters requires exposure times much longer than 30 minutes during which the differential refraction both in declination and right ascension may become appreciable. In this special case it is necessary to consult from time to time the guide telescope and to reset the position of the main tube in declination and hour angles as well as to change the rate of the drive.

E. J. Poitras and F. Zwicky

INDIVIDUAL VERSUS GROUP MEDICAL CARE

National interest is being centered upon the trial in Washington, D. C., of the American Medical Association on charges of violating the Sherman Anti-Trust Act by "boycotting" the Group Health Association, a local medical cooperative. The trial, which opened on February 5, is not expected to end before the middle of March, and, regardless of the verdict, it will probably exert considerable influence upon the practice of medicine in the United States.

The immediate occasion for the trial was the attitude of the American Medical Association and three other medical organizations towards the establishment of the Group Health Association in Washington. Typical of a number of medical cooperatives springing up throughout the country, this group sought to carry out a plan whereby the services of physicians and the facilities of clinics should be pooled and made available to subscribers on the basis of monthly payments. The Group Health Association, originally organized on an unofficial basis among employees of the federal government, received a $40,000 loan from the government Home Owners' Corporation and now has a membership of about 3,000.

The Trust Division of the U. S. Department of Justice, which is acting as prosecutor in this case, accused four medical societies and twenty individuals of monopolistic practices in coercing hospitals and individual physicians into refusing to treat G. H. A. patients. The four medical societies named in the indictment were the American Medical Association, the Medical Society of the District of Columbia, the Washington Academy of Surgery and the Harris County Medical Society of Texas. Fifteen of the individuals indicted are physicians practicing in Washington, while the others consist mainly of officials of the American Medical Association, including Dr. Morris Fishbein, editor of the Association's *Journal*, and Dr. Olin West, secretary and general manager of the Association.

The alleged "boycott" had gone on for two years when indictments were returned against the physicians and the medical organizations. These indictments were at first held invalid by the District Court on the ground that the practice of medicine was not a "trade" within the meaning of the Sherman Anti-Trust Act, but this ruling was reversed in March, 1940, by the Federal Court of Appeals, which upheld the indictment. The United States Supreme Court refused to reverse the ruling again, and remanded the case to the District Court for trial.

The views of the contending parties were elaborated in the preliminary statements made at the opening of the trial by attorneys for both sides. John H. Lewin, special assistant to the attorney-general, accused the defendants of obstructing the organization of the Health

Group and of handicapping its work. The District Medical Society, for example, was alleged to have sought to "crush and destroy" the G. H. A. by preventing any of its members from joining the new clinic's staff, by obstructing attempts to staff the clinic with non-members of the society, by personal attacks on the men who did join the staff, and by inducing all the local hospitals to join in the boycott by refusing courtesy privileges to G. H. A. practitioners. He announced that the first witnesses on his side would consist of well-known liberal surgeons who have been prominent in the group health movement and who would stress the social advantages of the plan.

William E. Leahy, counsel for the defense, criticized the management of the Group Health Association. He accused its founders of being motivated by commercial motives, and said that it was dedicated to the disruption of the traditions of the medical profession. He accused the cooperative of seeking to wipe out opposition to its medico-economic theories by undermining the American Medical Association and the District Medical Society. He accused medical cooperatives of being economically unsound and unable to provide patients with the care they promised. He denied the allegations that the medical societies had sought to hamper the cooperative's activities. Refusals of hospitals to allow G. H. A. practitioners to operate in their buildings were stated to have been motivated solely by a desire to keep their standards high. B.I.G.

NEW AUDITORIUM AT THE COLORADO MUSEUM

In the closing years of the last century, in a picturesque log cabin in the heart of the Rocky Mountains, a small collection of mounted birds and animals was assembled by lovers of the fauna of the West. From these humble beginnings the collection rapidly grew until it attracted state-wide attention, and in 1900 it was incorporated as the Colorado Museum of Natural History. A large museum building was constructed in 1908, with funds supplied by the state and by the city of Denver, to house the expanding collections of the museum. Every ten years since that date has seen the construction of new additions to the museum's plant. In 1918 the Standley Memorial Wing was constructed, in 1928 the James Memorial Wing was built, and the Phipps Auditorium—the newest addition—was begun in 1938.

The Phipps Auditorium, a new wing to the main building of the Colorado Museum of Natural History, was opened recently in Denver. The dedication ceremonies took place on January 11 and included speeches by the governor of Colorado, the mayor of Denver, the director of the museum and other dignitaries.

The wing is named in honor of former United States Senator Lawrence Phipps, of Denver, who presented $137,500 to the museum to construct the auditorium. In presenting the gift, Senator Phipps stated that he "had long appreciated the desirability of a suitable auditorium which would fulfil cultural needs by making a common meeting place for those interested in arts and sciences." A grant of $112,500 by the Public Works Administration supplemented Senator Phipps's gift.

The building, designed by Roland L. Linder, is 98 feet long and 140 feet wide, and seats one thousand people. Space is provided for a concert organ and the stage can accommodate a seventy-five piece orchestra. The latest type of standard and 16 millimeter motion picture projection equipment has been installed, so that educational programs for adults and children may be presented. Motion picture programs have been ar-

THE PHIPPS AUDITORIUM OF THE COLORADO MUSEUM OF NATURAL HISTORY
WHICH WAS OPENED RECENTLY AND HAS A SEATING CAPACITY OF 1000 PERSONS.

ranged each Saturday morning for children, and a Sunday afternoon series for adults will include lectures by naturalists, travelers and explorers.

Simultaneously with the construction of the Phipps Auditorium, work has been going forward on new cases for habitat groups in the Standley and James wings of the main building. These cases, illuminated with fluorescent lights, will have concave backgrounds with domed ceilings, and will have plate glass fronts 7½ feet high and 13 feet long. The habitat groups will represent fauna and flora from localities throughout the Americas, and will include scenes from Bering Sea Islands, the Arctic ice floes, the Alaskan tundra, the Bonaventure Islands off Newfoundland, and varied localities in Brazil. A number of specimens in these groups will be taken from the museum's bird groups, which will be dismantled. A group of W.P.A. artists, under the supervision of Curator Robert J. Niedrach, are now painting panoramic views for each group. B. I. G.

THE CENSUS

It is said that statistics are dull. They are to those who do not realize what they mean. But often they tell an absorbingly interesting story, as do those contained in the United States Census. Whenever we attempt to obtain a picture of the amazing changes that have taken place in this country, we are grateful that the first article of the Constitution provides that a census shall be taken once in each ten-year interval. The census records that have accumulated since the first census in 1790 now consist of more than 8,000,000 pages.

In 1790 about 95 per cent. of the population was rural; now only 25 per cent. live on farms. But in general to compare 1790 with 1940 is almost like com-

paring another planet with the earth. Even since 1900 the changes have been astounding. Forty years ago on the average about 17.6 persons out of a thousand died each year; now only two thirds as many. On the other hand, in 1900 about 30 children were born, on the average, per thousand of population; now fewer than 17. In the eight years from 1921 to 1928, inclusive, 2,200,000 more children were born than in the eight years beginning in 1929. The decrease in the young and the increase in the aged are presenting many new problems.

Habits, even food habits, of the people of the United States have changed greatly. For example, in 1889 the average per capita consumption of wheat per year was 223.9 pounds; in 1932 it was 162.2 pounds. The per capita annual human consumption of corn in the same interval decreased from 117 pounds to 21 pounds. On the other hand there were great increases in the consumption of citrus fruits, for example. In 1920 there were twenty million orange trees; in 1935, thirty-nine million. In 1920 there were three million grapefruit trees; in 1935, thirteen million. Food faddists will claim that these changes in diet explain the great decline in the death rate, but an analysis will refute the claims, for the greatest reductions in death have been in those of infancy and those due to infectious diseases. And those opposed to the eating of meat will be dismayed by the fact that its per capita consumption has decreased only a little.

Perhaps some of these figures may be thought to have a bearing on the fact that in 1920 the average value of farm land was $69 per acre and in 1935 only $31. There are, however, many other factors, including other habits of our people and international markets for farm products. A factor of major importance is the very great reduction in both the hours of manual labor and in the percentage of the population engaged in manual labor, the percentage of unskilled laborers having decreased by 25 per cent. between 1910 and 1930.

F. R. M.

THE SCIENTIFIC MONTHLY

APRIL, 1941

SEA—INSIDE

BEING THE STORY OF SEA WATER—WHERE LIFE BEGAN—WHERE LIFE ENDS

By Dr. IVOR GRIFFITH, F.R.S.A.

DEAN OF PHARMACY, PHILADELPHIA COLLEGE OF PHARMACY AND SCIENCE; PROFESSOR OF ORGANIC CHEMISTRY, WAGNER FREE INSTITUTE OF SCIENCE

"ONCE upon a time" (according to a legend which every history primer told in the days before primary education became secondary), King Canute of Danish England, to impress his warriors with the limitations that even a king must acknowledge, had his royal chair carried to a beach nearby, where the great North Sea flung its angry waves against a sandy slope.

"Stop!" commanded the king—and exactly as he expected it, the sea spat spray in his face and sand slid in his sandals. And accordingly, and ever since, Englishmen the world over, on the slightest provocation, sing "Britannia, Britannia—Rules the Waves."

In any event a king's attempt to stem an angry tide and to address the sea resulted in a ducking.

And somewhere in the literature of the so-called popular science, I came across another salute to the sea—penned by a word-wild chemist. Here it is:

> Oh, Sea, Thou saline and undulant aqueous solution of halides, carbonates, phosphates, sulphates, and other inorganic compounds. What mysterious colloids are dispersed within thy slightly alkaline bosom? What silent and unseen reactions vibrate in dynamic equilibrium, constantly destroyed and instantly restored, among thy unnumbered oscillating molecules? What uncounted myriads of restless ions migrate perpetually throughout thy tentatively estimated volume? What unguessed phenomena of catalysis, metathesis, and osmosis transpire in thy secret fluid profundities under increased pressure? What cosmic precipitates descend in countless kilograms upon thy argillaceous gelatinous, siliceous, diatomaceous and totally unillumined bottom? In short, most magnificent reservoir, what is thy flow-chart and complete analysis?

Which to my way of thinking seems to invite more of a drowning than a ducking.

Yet, in this bucketful of words, are reasons galore why the subject of this presentation can not in the compass of space available to it, find else than perfunctory treatment.

And so, with a guarantee that the subject will be treated in such wise that its depths will not be sounded, nor its surface sailed so tediously as to nauseate the most tender minded—let us, together—even when hope for a brief dissertation seems gone—sail on—sail on.

Shakespeare's sea dirge seems a most appropriate starting point:

> Full fathom five thy father lies;
>   Of his bones are coral made;
> Those are pearls that were his eyes:
>   Nothing of him that doth fade
> But doth suffer a sea-change
> Into something rich and strange.
> Sea nymphs hourly ring his knell,
>   Hark! now I hear them—ding, dong bell.

And the Bard of Avon, although he may have been neither a chemist, nor a biologist, in the modern acceptance of terms—was certainly an inspired, understanding interpreter of the origin and destinies of the material make-up of every living creature that has ever existed on this planet called earth. For it is from the sea that all living matter came—and the sea will at last inexorably demand the solubles of all the dead's dissembled residues whether it be by the short route of Shakespeare's, or by the longer road suggested in Bryant's "Thanatopsis":

> Old Ocean's gray and melancholy waste
> Are but the solemn decorations all
> Of the great tomb of man.

We shall not of necessity go down to the sea in ships—but certainly in chips—of molecular matter, borne to the ultimate solution of all our griefs, and wrapped in a blanket of water.

The Solution of Life and Death

Water preceded life on this planet. That is obvious—and reasonable, for where there is no water there can be no life. No matter whether life elects to serve its time in the simple, single-celled amoeba, or in the trillion-celled, complicated and conceited creature called man—short indeed would be its stay unless it had the varied services of its versatile ambassador—water. Life comes to us wrapped up in water, and death, so often the solution of all our prôblems, is also always a water reaction. Indeed, water gets us even after death, for it is largely through its agency that nature uses our substance over again in the fabrication of other creatures, so often improvements over the originals. And in this solvent cyclic scheme the sea is most important.

But, asks some one, whence came the sea? And the answer is easy if the imagination is elastic. According to that great group of guessers, the nebular hypotheticators, headed by the great Frenchman LaPlace, the earth was once devoid of water.

Diffident Drops of Rain

All one has to do is picture this world primordial—let us say a billion or two years ago—a hot ball of matter, broken here and there with fissures from which issued streams of molten rock. The original thin atmosphere has enlarged, and finally there has come a time when the water vapor produced by the electric union of hydrogen and oxygen arrives at dew point—and down come the first diffident drops of rain that this world ever knew.

And what a hissing, steaming reception the gigantic cauldron called earth afforded this first aqueous visitor. Back to the sky the water molecules scamper, there to await until the cold dome of heaven again condensed them into a cloud.

Cloudburst after cloudburst fall like Chinese regiments, and earth is a vast distillery. At last, however, heat gives in and water gains its victory. The skin of the earth is cool, and water remains in its cavities. Hot, muddy puddles grow to dismal ponds, and ponds to lifeless lakes—the lakes in turn become the dank primeval seas, and the seas the heaving oceans.

And yet no life.

Not a single blade of grass—not a creature on the land or in the churning water—nothing but bare, hot rock, hissing, crackling, crumbling, underneath relentless showers. Fire and water are the only busy realities—and fire is now the slave and servant—and water monarch of all it surveys.

Then came Life.[1] Just how—just

[1] E. E. Free, writing in the *Forum* about the generation of life, states: "We can now calculate what was the composition of the air and of the ocean when in the course of time the earth became cool enough to hold a watery ocean at all. The air contained no gaseous oxygen as it does now. All the oxygen had gone into chemical combinations. Whether the air con-

when—just why—no one seems to know. But certain it is that water mothered all things living. Certain it is too, that some day—far away—water will leave the earth again—and leave it like the moon, a cold and lifeless ball.

Dr. Lowell, the famous astronomer, went so far as to describe the agonies that our descendants would suffer, and the tremendous irrigation schemes which they would of necessity devise as their water supply grew less and less. Possibly the canals and waterways in Mars are evidence of such a current calamity in that far distant planet. This, of course, somewhat discounts Tennyson's song of water, which ends with "For men may come and men may go, but I go on forever."

The Bible is much less verbose in its explanation of the birth of the sea. For in Genesis 1: 10 we read—"And God called the dry land earth, and the gathering together of water called He Seas—and God saw that it was good!"

But the first sea-water was fresh water, free of its present plethora of solubles, and certainly lacking in salt. Yet knowing the hunger of water for that which is substantial, solid and soluble, it is easy to surmise how soon the sea came to be briny and as full as it is of something of every element.

From the first fresh water of universe to the present state of the sea is a tremendous development. Contemplate, for instance, upon this estimate of chemical content of just one cubic mile of old Atlantic's waters, as compiled by some professor who prefers this sort of dabbling arithmetic to teaching horse sense to his classes. Here it is: 128,284,403 tons of sodium chloride or common salt; 17,946,522 tons of magnesium chloride; 358,270 tons of magnesium bromide; 1,400 tons of fluorine combined as fluorides; and a minimum of 90 tons of iodine combined as iodides; to say nothing of the thousand and one other solids contained in lesser proportions.

Indeed the composition of the sea[2] is as

tained any gaseous nitrogen is uncertain. What it unquestionably did contain was carbon monoxide, the deadly gas,—existing in the exhaust of automobile engines—and prussic or hydrocyanic acid. In the primitive ocean, having absorbed gases, and therefore full of deadly prussic acid and overlaid by an atmosphere containing large amounts of a poisonous gas no less deadly, the first life arose. It is reasonable to assume that there occurred some natural chemical synthesis of glycocoll or of a similar material. Glycocoll is the simplest amino acid, composed of four elements, oxygen, hydrogen, carbon and nitrogen obtained either by destructive treatment of protoplasm with caustic chemicals, or by a succession of chemical reactions between the three substances of the primeval ocean mentioned: prussic acid, carbon monoxide and water. During the three or five billion years which were to elapse before the period when we find actual traces of life in the rocks, there was ample time for such simple substances, as glycocoll, to undergo additional chemical changes and combinations and to be built up into more complicated forms perhaps at last into substances equivalent to our modern protoplasm."

[2] The composition of ocean water differs in various parts of the world. Generally speaking, it is less concentrated near the shores because of the influence of fresh water rivers. The following is an analysis of the water in the English Channel ten miles from the coast of France, which had a specific gravity of 1.026 at 15° C.

Gaseous contents	In one kilo. liters	In one liter. liters
Atmospheric air	0.0120	0.0123
Free carbonic acid	traces	traces
Free hydrogen sulfide	traces	traces
Solid contents	Gm.	Gm.
Potassium chloride	0.09763	0.10019
Sodium chloride	26.09300	26.78913
Lithium chloride	0.00042	0.00043
Ammonium chloride	0.00178	0.00183
Magnesium chloride	3.19300	3.27700
Sodium iodide	0.00920	0.00944
Sodium bromide	0.10605	0.10882
Magnesium bromide	0.03084	0.03163
Calcium sulfate	0.09017	0.92540
Potassium sulfate	0.00919	0.00943
Sodium sulfate	2.57250	2.64012
Magnesium sulfate	0.32736	0.33597
Magnesium phosphate	0.00046	0.00047
(Ammonio-magnesium) phosphate	signs	signs
Calcium carbonate	0.13600	0.13959

A—Sea. B—Pool. C—Gate. D—Trenches. E—Salt basins. F—Rams. G—Shovel.

SALT FROM OCEAN WATER
AGRICOLA'S "PROCESS."

complicated as the composition of the land that it covers, and of the silt and soil that surrounds it—for it is natural that a share of every substance on and in the earth must sometime find the sea.

Magnesium carbonate	traces	traces
Iron carbonate	0.00021	0.00021
Manganese carbonate	signs	signs
Silicic acid	0.01420	0.01457
Organic matter	signs	signs
Pure water	966.50646	991.91577
Total	1000.00000	1026.30000

Further out from shore the proportion of sodium chloride may rise to 36 or 37 parts per thousand. In inland seas the proportion of salt is often very much greater than that of the ocean, thus the amount of solids in the water of the Great Salt Lake of Utah has varied between 15 and 20 per cent., while in the Dead Sea of Palestine there is 27 per cent. of solids.

How little understanding of this important fact is found in the words of another poet who has taken every adjective out of universe leaving this barren bit of pouting poetry:

> The earth is just a lot of dust,
> The sky's a lot of air,
> And the sea's a lot of water
> That happens to be there.

What a fool's philosophy is reflected in the words and what a monument to ignorance. For in the salt of the sea alone is sufficient romance of origin and diversity of use, to intrigue not only those who write, but those who also think.

Salt, or sodium chloride as the chemist calls it, is a benign alliance of two malignant elements, sodium the swashbuckling, arch-enemy of water, and chlorine, the green-eyed ugly gas, so poisonous to life that the god of war himself has used it as a mighty weapon. Yet when wed, these toxic devils lose their elemental fury, and lead a useful, mild existence.

The physical properties of salt bespeak its mild-mannered meekness. Soluble in water, non-toxic in moderate amounts, non-combustible and stable to a high degree, it becomes one of life's most valuable servants. Without its competence of salt the animal body would soon be derelict, for as we shall later prove, every living cell in that busy tissue called blood must have its share of salt to enable it to keep life's fires burning.

Yet by the same token, salt in excess is a violent poison, and in China suicide by salt is said to be a much maneuvered means to an economical end. Shipwrecked mariners know full well the menace of drinking sea water—though sea water runs in their veins.

But how or why came the salt of the sea is another moot question. In Child's "Geology" of 1832 we are told that "He who formed the earth and the sea knew that by saltness only could the ocean be kept sweet and that this saltness is abso-

lutely necessary in order to preserve the ocean from putrefaction." And this is not as childish as it sounds.

If it is true that the earth was formed by the gradual cooling of a molten mass, it is reasonable to suppose that the primeval ocean formed out of an atmosphere of water vapor was fresh-water ocean. Then by the incessant weathering and solution of the rocks the salt has been leached out and has accumulated in the ocean from which there is no outlet for its surplus material, except for its volatiles which go back to the atmosphere by evaporation. There are some who believe that much of the salt in sea water is actually produced there by interaction between sodium sulfate and calcium chloride, both of which are carried into the sea by the rivers that constantly feed it. By a merry exchange of acid radicles the calcium chloride is converted into the less soluble calcium sulfate or gypsum, which sinks to Davy Jones's locker, and the sodium sulfate into sodium chloride or common salt, which gives the sea its salty sweetness. Such a process is a very simple, yet a very certain bit of chemistry.

And millions of years of continuous washing and bleeding of the solubles of earth to the sea have taken their toll from the land, exactly as the land has, at times, taken its toll from the sea.

The Sea Caught Napping!

For in the hectic, heaving changes that have come to the surface of earth, the sea has more than once been caught napping. During such upheavals, sections of ocean have been cut off by the careening land, to form isolated salt lakes. The sun has dragged the water from many of these lakes, leaving large deposits of salt and other soluble substances. Some such deposits are found right on the surface of the earth and others are underground, having been covered by more recent formations.

In other words, what man is doing to-day in isolating tracts of sea-water and separating the salt by solar evaporation must have been practiced by nature on a large scale throughout the ages. The alternating layers of salt and clay that are found in some rock-salt deposits are explained by the fact that the clay represents the mud that was brought into the lake during the rainy seasons.

The immense salt deposits of Utah and Nevada were once the beds of prehistoric salt lakes, and so is our famed Great Salt Lake the remains of a large inland sea that once covered that particular area. Should the climate become drier than it is now the shrinkage of the Great Salt Lake, which has been going on for ages, will continue until a huge salt deposit remains.

All over the earth tremendous deposits of salt attest to the drying up of pieces of the primeval oceans, and somewhere in the Carpathian mountains is the most noted of them all.

The Chamber of Commerce of Weilicza, where these salt mines have been worked since the eleventh century, proudly announces to the world that the unworked deposits are still 500 miles long, 30 miles wide and nearly half a mile deep—which comforts one with the thought that although all the coal and the oil of the world will some day be depleted, there will always be salt enough to season our soups and to keep our Sunday mackerel sweet and wholesome. But enough for the moment of such landlubber reflections, and let us hie to the sea again.

Now there are so many seas—good seas and bad seas, deep seas and shallow seas—blue seas and black seas—live seas and dead seas—that for our specific pedagogic purpose here, we had better select just one—row with courage to its very center, and then with one gargantuan splash, plunge, eye-open, to its saline cellar.

THE SEA YOU SEE IS THE DEAD SEA

You are now in Palestine, and in deep water already. The sea you see is the Dead Sea—the saltiest sea in existence. It is deliberately selected as our sample sea because it is different, and because the world strangely owes it an apology. Maligned for centuries by people who did not understand its real character, called "Dead" because it is so heavily loaded with mineral salts that nothing living seeks its waters—charged with evolving such a miasmatic vapor that even sea-gulls are sea-sick when they essay to cross it; reported as being so buoyant with salt that those who sailed it never carried the customary life savers—such has been the reputation of the so-called "Dead" Sea. Even the climate of the valley where it sullenly rests is reported in old travelers' tales as dreadful and deadly.

But the old "dead" sea was only "playing possum." Within the last few years so many things have happened on its shores, and so many age-long beliefs disproved, that "the Dead Sea to-day is a thing of life, pulsating with health and conferring benefits on thousands of human beings." These are the words of Major T. G. Tulloch,[3] upon whose recent lecture before the Royal Society of Arts in London, England, these paragraphs are freely drawn.

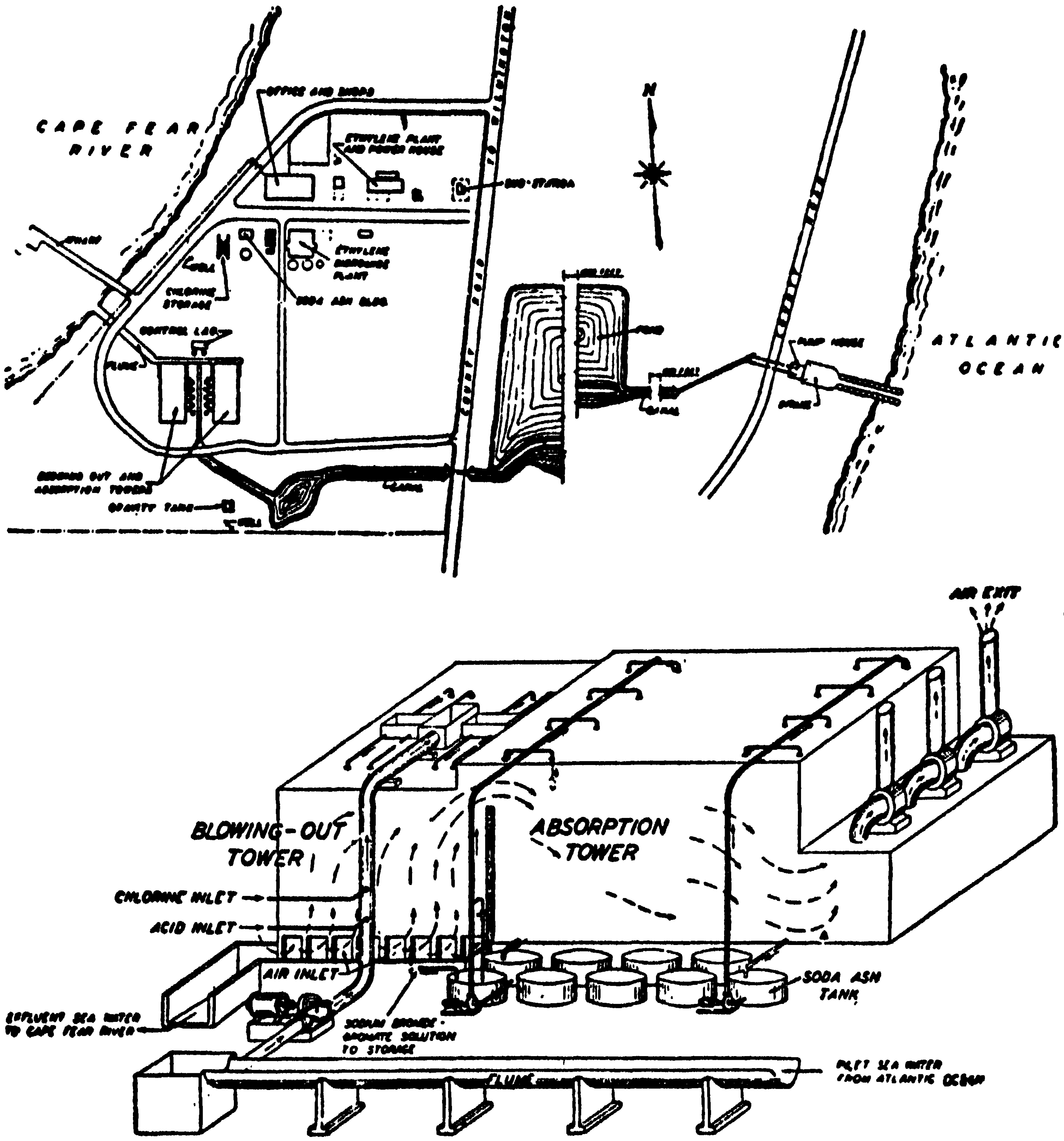
Palestine is governed under a British mandate, and Major Tulloch and his associates being Britishers have readily secured a concession to exploit the possibilities of the Dead Sea after numerous analyses had convinced them that its waters were a vast potential source of common salt, potash and bromine. They organized Palestine Potash, Limited, which started practical work in 1930. The astonishing progress made since then amply confirms their judgment, and proves that man at last has been able to do what the crab, the skate and the lobster have done ever since their origin—namely, to grab and grasp for their own the chemicals that exist in the sea.

As the fresh water from the Jordan and other streams dilutes the surface water, sounding experiments were made which showed that the salinity increased in proportion to the depth, until at something like 200 feet a constant analysis was noted. A 30-inch pipe line, 2,800 feet long, was therefore laid out from the shore to approximately this depth, and pumps provided which discharge into an open canal. Along the shore and encircled by the canal, great evaporating pans covering thousands of acres were constructed. Most fortunately for the success of the venture the local soil, which is alluvial clay, proved impervious to leakage, since a porous soil would have involved an enormous expense in pan construction.

The pans are about two feet deep, and the water from the canal goes first to the upper series of pans. Evaporation is by the sun's heat, assisted by the steady breeze which blows all day from the south and all night from the north for most of the year. As evaporation proceeds, the concentration of salt increases, until the least soluble of them, namely, sodium chloride or common salt, is first deposited. The liquor is then run into the next lower series of pans, where, under continued evaporation, the double salt of magnesium and potassium chlorides known as "carnallite" is thrown down. The remaining liquor from these pans is heavy with magnesium bromide, from which bromine itself is separated easily. Potassium chloride, 98 per cent. pure or better, is separated from the carnallite by washing with fresh water.

The important part which the mineral resources of the Dead Sea are destined to play in the world's economics is indicated not only by reason of the simplicity

[3] From Arthur D. Little's *Industrial Bulletin*.



ETHYL-DOW CHEMICAL COMPANY PLANT AT KURE BEACH, NORTH CAROLINA.

of their production, but also on account of their vast quantities, which, computed to close limits, are as follows:

	Millions of Tons
Magnesium chloride	22,000
Sodium chloride (common salt)	11,000
Calcium chloride	5,000
Potassium chloride	2,000
Magnesium bromide	1,000

Moreover, it is estimated that an additional 40,000 tons of potassium chloride is brought into the sea each year by the streams flowing into it.

Major Tulloch calculates that if potash from no other source were available the quantity existing in the Dead Sea would supply the world's requirements for over 2,000 years, and by that time your potash and mine will have sailed the seas again.

Shipment is made by motor truck to Jerusalem, twenty-five miles away, and thence by rail to the docks of Haifa, some 115 miles in all.

Astonishing as are the values revealed

by this development, the present status of the Dead Sea as a health resort is even more remarkable in view of its previous sinister reputation. Major Tulloch tells us that the company has been at work continuously, summer as well as winter, for over four years, and there has not been a single case of illness among the several hundred workmen, though many of them came from cold northern climates. Last year a seaside and health resort named Kallia (which is Latin of a kind for potassium), adjacent to the potash company's works, was opened on April 30, and was patronized by hundreds of visitors daily all through the summer; and on one occasion, in the middle of July, no less than 2,000 vacationists came to dance to the tunes of a local Ben Bernie, and to bathe in the light of the Zion moon.

The Live "Dead Sea"

The remarkable healthfulness of the northern shores of the Dead Sea appears to be due to several factors, one of which is the unique fact that at 1,300 feet below sea level the air is so much denser that 6 per cent. more oxygen is brought into the lungs at each breath than is the case at normal or sea level. There is, moreover, an absence of fogs and an extraordinarily clean, pure atmosphere. Added to this are the stimulating and energizing effects of bathing in the densely saline waters of the Dead Sea.

And better than anything else, so we are informed, bathing frequently in this buoyant sea has a beneficent dwindling action upon those, who having honestly won their cream puff figures, mostly by exceeding the feed limit, hanker after streamline design and a greater girth control.

Another clever and spectacular British achievement is a process originating in Teddington, England, and described in a recent bulletin of the Arthur D. Little research organization:

With this new development it has been found possible to pass ocean water through a succession of filters which entirely removes its salt content. Salt dissolved in water may be considered as a mixture of equivalent amounts of caustic soda and hydrochloric acid intimately mixed. In the English process, the salt solution is passed through layer number one, which absorbs the caustic soda, then through layer number two, which absorbs the hydrochloric acid, then through a similar pair of layers to repeat the process on what may have escaped the first stripping. In this way, by removing the two parts separately, salt can be eliminated, whereas there is no analogous method of removing the chemical sodium chloride (salt) as a unit, all at once.

Perhaps the most interesting part of the English method is the nature of the absorbents used, which are not mineral, but are synthetic organic chemicals of the formaldehyde resin type. The base-absorbing resin is prepared from tannin and formaldehyde, and the acid-absorbing resin from aniline and formaldehyde. Regeneration is possible, so that a cycle can be maintained. So far, the economics of the system have not been investigated, but *Chemistry and Industry*, the British periodical, has a real enthusiasm for the possibilities for this process which "was the work of an ordinary Englishman working in a British Government Laboratory." Perhaps "ordinary" should be qualified a bit in view of the result achieved.

And now for a sea-swing closer to home—and a real story of modern enterprise. It has been said by an English physicist whose recorded dreams are his profoundest gifts to science, that the released atomic energy from one bucketful of sea water would provide power enough to dynamize the whole world's mighty fleet of ships. But he did not envision the reality nor enlighten us as

to how that energy might be secured to put to work.

To the Sea for Power

Not so, however, with the diligent chemists of America, whose more practical minds sought to get from sea water that which it would less grudgingly give.

For instance—when the automobile became a democrat, and its owner a plutocrat, the old-fashioned fuel would hardly suffice for so sensitive and speedy a driver. The high compression motor growled and grunted with every explosion of gas—and something had to be done to stop it.

Along came Ethyl—tetra-ethyl lead—and ethylene dibromide—in the manufacture of which bromine was most essential. Added to gasoline these chemicals silenced its knock.

Bromine and Gasoline

Now bromine is sister to chlorine, and with the rest of the haloid quartette, fluorine and iodine, spends most of her time out at sea. Ten years ago, a paltry two million pounds of bromine sufficed to fill the medicinal and industrial needs for this element and its compounds, and they made it mostly from inland bitterns and brines.

But when the anti-knock craze hit the producers of motor fuel the usual sources of bromine were totally inadequate. And so to sea the chemists went—and so successful was their queer quest that ten times two million pounds of the stuff now annually come from the sea. Mind you, this is in spite of the fact that only four grams of the element are contained in every gallon of brine.

The Ethyl Gasoline Corporation and latterly the Dow Chemical Company, at the mouth of the Cape Fear River on the Atlantic shores, beyond a promontory that keeps the sea from river dilution, have a magnificent modern plant which pumps a billion gallons of sea a day through its vast extracting processes. The bromine is dislodged from its nautical partnerships by the use of chlorine, its zealous sister, a displacing technic familiar even to freshmen. In this way 15,000 pounds of the vicious element bromine are daily claimed from the sea. For the time being other substances are not recovered, although a special research is now under way to broaden the scope of the work.

Once it was thought that sea water was a simple solution of salt. Modern analyses, however, reveal its much greater complexity. Out of the ninety-two known elements, forgetting for a while the dizzy isotopes recently brought to confound an already confounded chemistry, thirty-two separate elements have been separately identified in sea water. Many of them occur in such small quantities that their presence can be revealed only by the spectrographic analysis.

For a long time there was a tendency on the part of the chemist to disregard the importance of those substances which are found in the sea water in minute amounts, but recent discoveries in the physiology of nutrition have taught us to pay more respect to them. We know to-day that iron, copper, manganese and iodine are necessary for the normal functioning of our bodies. Traces of silver and gold and radium are also found in sea water. More radium exists in the mud of the sea than in the ordinary rocks of dry land, Dr. Robley D. Evans, of the University of California, has found. His tests show that radium is being deposited constantly by ocean waters. There is no hope of mining sea mud for radioactivity. Dr. Evans made his experiments merely to test his new method of detecting extremely minute amounts of radium and radon gas emitted by radium. Each ounce of mud contains three trillionths of an ounce of radium.

And who knows but that this radioac-

tivity has much to do with the teeming, pulsing life of the sea, that undetermined something that grants the sea its great fertility. The triple play—Shakespeare to Hamlet to Horatio—"There are more things in heaven and earth than are dreamt of in your philosophies"—must contemplate the sea as well—for as yet the secrets of the sea are only half divulged. For there is a vital-energizing force in sea water that is beyond its chemical content.

Home-made Seas

Artificial sea water may be manufactured, and it has been used more or less successfully for a number of years for inland bathing purposes.

But such waters have not been found suitable for fish. Whether this is due to the absence of certain chemicals, normally present in natural sea water in minute amounts, or because the water is not "alive," is still as much a mystery as it has ever been.

That there is still something else to be discovered is indicated by substantial evidence. It is known by fish culturists that comparatively large quantities of artificial sea water become quite suitable for fish after a very small quantity of natural sea water has been added and it is allowed to stand for a week or so. The water apparently becomes "alive," as opposed to the "dead" water which results when the various chemical constituents of sea water are dissolved in fresh water.

SIXTEENTH CENTURY SALT MAKERS
BOILING DOWN BRINE SOLUTION.

Crystalline sea salt of commerce, or the salts obtained by evaporating natural sea water, when dissolved in fresh water, likewise do not produce a water that is "alive," and the water prepared in this manner is practically always inferior to that prepared from chemicals.

Aquariculturists who wish to manufacture artificial sea water can have a druggist prepare the following formula: Sodium chloride (U. S. P.), 36¼ ounces (troy weight); magnesium chloride (C. P., crystallized), 10¾ ounces; magnesium sulfate (U. S. P.), 4½ ounces; calcium sulfate (C. P., anhydrous), 1⅝ ounces; potassium sulfate (N. F.), 1 ounce; magnesium bromide (C. P., crystallized), 2 drams; and calcium carbonate (U. S. P.), 1¼ drams.

This composition should be dissolved in about nine gallons of spring or fresh river water, and then sufficient water is added until the specific gravity, which is determined by means of a hydrometer, is between 1.030 and 1.032, the range which most fish prefer.

While water of approximately the same composition has been used with a certain amount of success in a number of public aquaria and laboratories studying marine life, if a small amount of natural sea water—about one gallon to ten of artificial water—is added and it is allowed to age for a period, the results are very much better.

The Noble Metals

It has been estimated that there exist dissolved in the sea 13,300 million tons of silver, and a cubic mile of sea water is said to contain nearly a hundred mil-

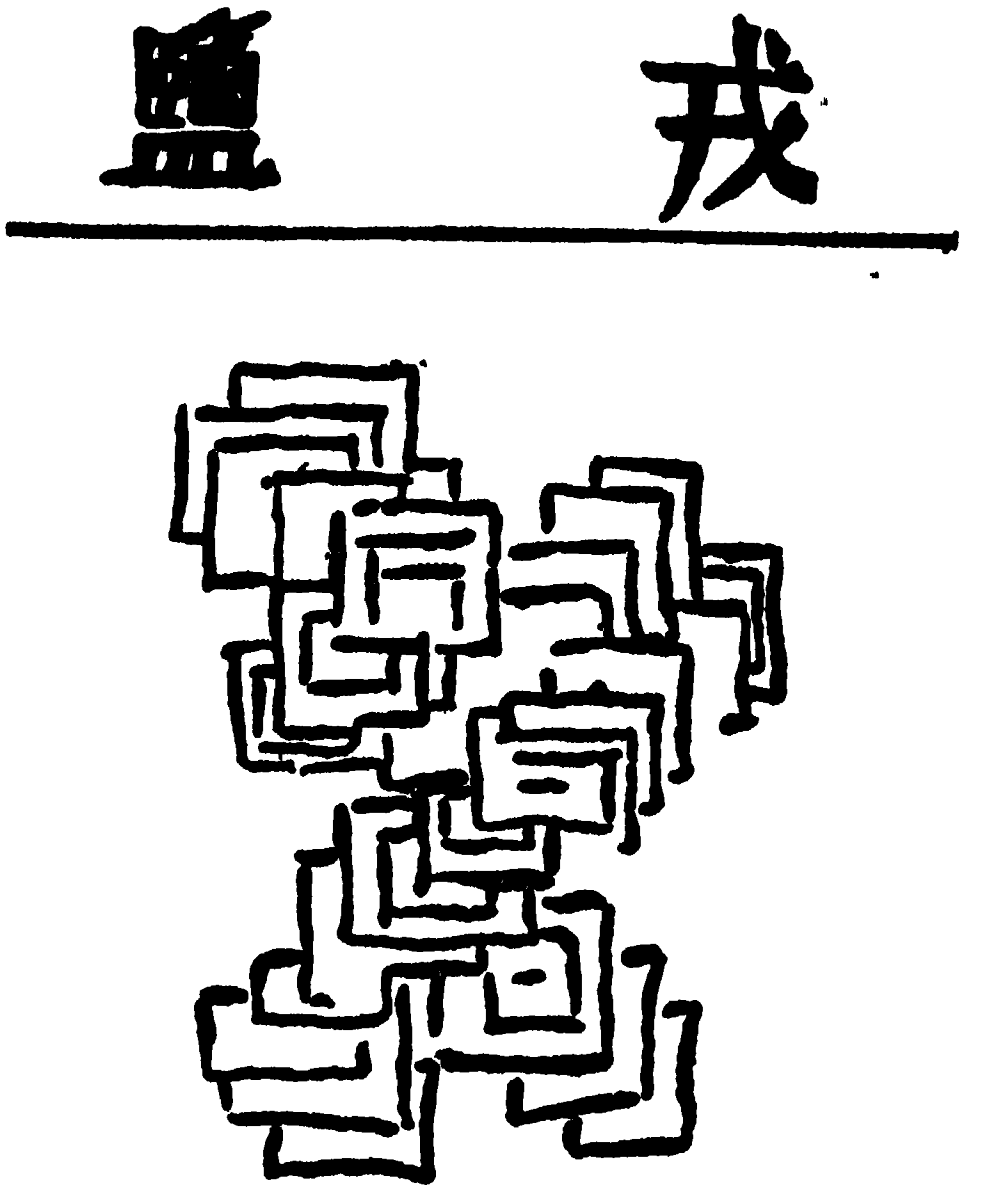
lion dollars worth of gold, which despite a giddy government's attempt to corner that coveted metal, is as yet as useless a gold as the gold that gilds the goldfish. And though the actual gold content of the sea varies from one to three ten-thousandths of a grain to the ton[4] some day—and perhaps not such a faraway day, this metal of metals will be mined from the sea. Fritz Haber, the German chemist, who successfully mined the air for niter, failed to practicalize the claiming of gold from the sea—but some day a Scotchman may do it. Indeed Dr. Stewart (whose name suggests a Caledonian origin), of the Dow Chemical staff, operating the sea water bromine plant in Carolina, specifically states that "now that the recovery of bromine, which is present to an extent of less than four grains to the gallon has been successfully executed, it does not seem beyond reason to expect the chemist of the next decade to extract gold from sea water commercially."

Midgley, vice-president of the Ethyl Corporation, is not so enthusiastic, however. This is his reaction.

> There is a much bigger problem associated with sea water upon the solution of which depends the future welfare of millions of people. This problem is the commercial extraction not of gold or of bromine but of water itself from sea water. No one can say that water is present in too small a quantity to be recoverable. The present price paid for water in arid lands for irrigation purposes indicates that the value of the water in sea water is about the same as the value of the bromine at present prices.

And now let us turn for a while to some livelier aspects of the sea. Let us get personal—admitting a lot, but imagining more.

[4] Since Dr. Haber published his analyses, new quantitative analytical methods have been developed and applied. That variations in concentrations exist seems beyond dispute; however, one does not need to locate such a proposed extraction plant at the points of low concentration. Hence the minimum concentrations reported are beside the point. It is only high concentrations that need be considered as pertinent and Dr. Haber himself reported sample concentrations up to 8 parts per billion.



HOPPER-SHAPED SALT CRYSTALS
DRAWN AFTER A FIGURE IN THE PENG-TZAO-KAN-MU, OLDEST CHINESE TREATISE OF PHARMACOLOGY AND PHARMACOGNOSY, WRITTEN 2700 YEARS BEFORE CHRIST WAS BORN.

Evolution we define as change, than which there is nothing more permanent. The evolutionist acknowledges the unceasing change that goes on in cosmos, earth and life. For him the everlasting hills do not endure; he knows that the continents lift and subside; that the very elements of which earth and suns are made are forever transmuting themselves. Energy as well as matter—is shifting from one form to another. Nothing is static in the inorganic world; nothing is fixed. And man's climb first to the top of his Simian roost, and down again to his present two-legged state, has been a long and arduous achievement.

Evolutionists claim that all life was once marine or submarine—that the antecedents of every creature now living, originally like Venus, came from the sea. And there are many evidences about which incline to prove their story—although a question they have not been quite able to answer convincingly is where the sea secured its life.

Sea Inside

One of the slender threads wherewith they join their arguments is in the remarkable comparison which they make between animal blood and sea water. When blood is permitted to coagulate, the clear, rather colorless serum or plasma which separates, has, exclusive of its protein content, a composition very like that of sea water. It contains so much sodium chloride—so much phosphates—and carbonates—and so much combined iodine—in a ratio similar to that of sea water.

The contention is that whereas we were once limpid jellyfish that floated lazily on the dark primeval seas—we are now so evolved and involved that a share of the sea floats diligently within us, with an ebb and flow in every heart beat.[5]

Certain we are that life in us could not get along without the sea elements that race in our blood stream. Lacking the little salt that parades its molecules constantly—through sleep and waking periods in us—no longer would life remain intrigued.

Blood, lost through hemorrhage, may not be replaced with distilled water else the recipient dies—but the injection of an artificial sort of a sea water, which the Pharmacopoeia calls "Physiological Salt Solution" is a safe procedure.

This aqueous solution contains slightly less than 1 per cent. of common salt (0.85 per cent.).

Red blood cells are dissolved to death by pure water. By salt solution they are kept whole and alive.

States an old Welsh proverb in a much clumsier English dress: "Salt brings balm to every human woe—but it must be as salt of tears, as salt of honest sweat —or as salt in the heart of the sea." The old Welshman whose nimble tongue and nimbler wit composed this Cambrian proverb could hardly have known that the salt of tears, the salt of sweat, the salt of blood and every body salt are cycled from the sea.

Salt is eliminated in all our body secretions. The average weight of salt consumed by sensible persons is about one-half ounce a day. Only a little more than one sixth of this amount is retained as necessary to bring the acid to our gastric equipment, and for other uses, the rest of it being eliminated. Thus there is a ceaseless cycling of salt from the quick to the dead, and back to the quick again. It is for this reason that drinking water containing an abnormally large amount of chlorides is looked upon with suspicion, unless the presence of these chlorides can be explained on other than a sewage basis.

[5] It will be observed that the cells of the human body are aquatic, since they live as small groups or communities in a watery environment regulated by the blood stream and their own individual efforts. The human beings of the body politic, on the other hand, are outwardly terrestrial and live on dry land. But, thanks to Darwin and the others, encouraged and strengthened by spirited opposition to their views, it is now generally accepted that we humans have developed from animals who were inhabitants of the ocean. All these ages we have carried parts of the watery environment with us. Those who by chance read these words do so by looking through thin films of salt water supplied by the lachrymal glands. If these vestiges of the original watery environment of the body politic were allowed to dry up blindness would ensue. They may throw the book away with a sigh of relief, in which event they find momentary refreshment by increased absorption of atmospheric oxygen, again through a thin layer of salt water lining their lungs. Later on, they may listen with approval to criticisms of the wild ideas expressed in this paper; but they can do so only by using little bodies of salt water which constitute essential parts of their inner ears. Our forgotten ancestors learned to see and to breathe and to hear in salt water and we must perforce do the same, so that we are at least partly aquatic. To express it differently, the surfaces of our bodies in contact with air are all coated with dead cells (skin, hair and finger nails). The surfaces, external and internal, made up of living cells (cornea of eye, inner ear, lungs, digestive, urinary and reproductive tracts) are all wet, *i.e.*, aquatic.—Scientific Monthly, 42: 246, 225–226, March, 1936.

WHY THIRST?

And every one knows that salt is essential to the welfare of the animal body. It has been shown that animals wholly deprived of it will weaken and eventually die. Indeed, there are few things more distressing than the salt hunger that comes from an insufficient amount of salt in nourishment. One of the chief functions of salt in the body is to provide the proper concentration for the blood serum. It seems that the proper functioning of the body depends upon favorable conditions of osmotic pressure. In order to maintain these conditions it is necessary to regulate the intake of water and salt within certain limits. The attempt on the part of the body to establish an equilibrium is recognized when we recall that the taking in of a large amount of salt causes intense thirst and on the other hand the excessive drinking of water produces a desire for salt. Even sweat has its share of salt, that of humans (who normally perspire nearly a quart a day) containing 3/10 of 1 per cent. in the female, and nearly 4/10 of 1 per cent. in the male!

Then there is our mite of iodine from the sea. And what a mite it is. Yet without it we are hopeless idiots unable to regulate our body fires, and everything we do we either overdo or underdo, depending upon the functioning of the iodine gland that keeps us in touch with the sea.

OUR MITE OF IODINE

This gland, by the way, is present in all vertebrate animals, beginning low down in the scale, with the eels and lampreys and complicating its structure and increasing its size as the evolutionary scale increases. In fish, the thyroid occurs as small scrubby patches little larger than pin-heads and scattered along the important blood vessels. Then in the reptiles it is a little larger and more compact, and still more prominent among the birds and the mammalia. But it is in the primates and in man that it attains to greatest size. The farther we are from our early home in the sea the larger the thyroid gland—and since evolution never stops its course more than likely man's appearance may eventually change, because of thyroid growth, so that he will no longer be the good-looking creature he now thinks he is—but he will have evolved into a pop-eyed, fat-headed, chinless creature—the space between his chin and his collar button having been taken over by his constantly enlarging iodine plant.

But that is too far off to worry about. Much can happen in a million years. Listen. The high tide of this element in the blood is about one grain of iodine to ten million grains of blood, or less than a hundredth of a grain to the entire circulation. The reservoir of iodine in the body, namely the thyroid gland, only holds a third of a grain (about 25 milligrams) and in order to keep this reservoir full one only has to consume per day, in his food or drink, less than a thousandth of a grain of iodine. No wonder some folks believe in homeopathy. It seems the Great Designer did!

FRY-DAY

I do not know the canons of the Church of Rome, nor its history, well enough to identify the origin of the custom of sea-food for Friday. In any event it is a good custom, for though Friday euphoniously admits of a fry—fried fish will furnish our weekly requirements of iodine far better than anything else we might fry, or try. And so, much like the Mosaic indictment of pork whereby our Jewish friends are denied the blessed privilege of a ripe red ham unless they call it pickled salmon—Friday for fish may have had a hygienic sanitary origin.

Moses may have fooled Pharaoh with a lot of phony tricks, but he led his people with real thinking.

And while we are speaking of these primitive, intuitive health precautions—listen—while London was yet a muddy fen and Rome a rambling village—China had a mind of her own, and a culture of her own as well. When the civilizations of Athens and Rome were still in knee pants—Cathay had spun her cycles. Four thousand years ago the Chinese had guessed that goiter was a dietary deficiency disease—that it mostly attacked people who shunned the sea and found their safety far inland—that it yielded to treatment with sea medicaments—salt of the sea—sponge from the sea—sea weeds and coral.

Yes, indeed, the art of the ancients was in knowing how—not why.

Burnt sponge was used in medicine for centuries, only to be displaced in modern times by iodine and its compounds. Indeed the first Pharmacopoeia of the United States, published in Boston in 1820, gave it a place though it was deleted in the next revision. So too was a variety of burnt sea weed included. To-day burnt sponge and bladder-wrack are still used by the eclectic physicians, who believe that these natural products, in contradistinction to iodine or its definite artificial compounds, contain a structural "something" that must be very different from pure iodine. And they may be correct in their assumption.

A strange fact regarding sponge is its property while alive of abstracting iodine from sea water. In some tropical species of sponge the iodine content of sponge ash may run as high as 8 to 14 per cent., while sea-weed ash from which some commercial iodine is obtained rarely exceeds 1.5 per cent. Since it is assumed that all the iodine in sponge comes from sea water and sea organisms, it has been calculated that one pound of sponge contains the total iodine content of twenty thousand tons of sea water. Rather a remarkable figure.

Most sea organisms, plants and animals too are rich in iodine. Even the humble oyster, whether brought up in well-aired beds or not, contains his share of iodine.

Sea water contains about 1/300th of a grain of iodine to each gallon (0.05 mgm per liter). It is of interest in passing to note that the Great Salt Lake of Utah contains but a little more iodine (about 1/200th grain to the gallon), whereas it contains five times as much salt.

Of interest, too, is the fact that we have enough iodine in the sea to last our children for a long, long time. Practically all the iodine on this planet is in the sea and another dabbler in useless arithmetic has figured that it amounts to a few pounds short of sixty billion metric tons which antiseptically and biologically leaves us nothing to worry about.

South Carolina has capitalized the alleged heavy iodine content of her vegetables by ridiculously adding the word *Iodine* to her automobile license plates, and by circulating a silly slogan—

A potato a day
Keeps goiter away.

Which shows how the low surface tension of ignorance can make even the so-called authorities run away from sound sense. The "Carolina Moon" *will out.*

Yet much has been constructively done to awaken the world to the realization of the fact that iodine deficiency in food is the commonest cause of goiter and other diseases. The resulting world-wide movement to insure the presence of sufficient iodine in the diet to prevent these dreaded diseases is one of the greatest prevention measures undertaken by man in the interest of good health. Yet the wholesale methods used have not been without danger, for there are types of gland affections which are radically aggravated by iodine medication, and are only amenable to surgical care.

Had we more space at our command we might have dwelt more fully upon these prophylactic measures—such for instance as the now tabooed charging of

drinking water with iodides, or the general use of iodized salt. Iodized salt, containing from 0.02 to 0.025 per cent. of iodine in the form of iodides, is now available in the stores. But we repeat that with community medication of this kind, it must not be overlooked that harm can come from feeding iodine to individuals who already have enough or too much, just for the sake of catching those who have too little. It is a matter always of individual treatment. Nor must we overlook the danger of inducing in the individual through over-dosage that uncomfortable chemical disease, iodism. Indeed it is not always a matter of over-dosage, for to iodine as well as to almost everything, there are persons who display idiosyncrasy.

Yet in spite of our alleged progress in the etiology and treatment of goiter and other thyroid disorders, warning comes recently (April, 1935) from Dr. Arnold Jackson, of Madison, Wis., that thyroid diseases are decidedly on the increase. As many as four fifths of the girls and one fifth of the boys living in the great goiter belt, which extends from Boston to Seattle, are afflicted with goiter, Dr. Jackson found in a nation-wide survey of the problem. Cretinism, resulting from this type of goiter, is more prevalent in the United States to-day than at any time in the nation's history.

But we are digressing too far from our text—and postponing too long our "Amen."

So—abruptly—come we to the close of our sea sojourn—stopping at the harbor of "just enough." There was much more of the sea to be seen—and more to contemplate—but like every other voyage, even a verbal voyage must have its sensible end.

One hope, however, finds expression here—and it is that my readers, touching ground again, will find their land-legs not unsteady, nor their minds still too much at sea—for all the odd things we have said.

And I end as I began—with a swinging song that carries the cry of the primal cell—the lilting, liquid, lullaby urge of every living particle that constitutes our bodies—the death-bed dirge of every animate entity.

I must go down to the seas again, for the call of the running tide
Is a wild call, and a clear call that may not be denied.
And all I ask is a windy day, with the white cloud flying,
And the flung spray—and the blown spray—and the sea-gulls crying.

—*Masefield.*

PREHISTORIC TRADE IN THE SOUTHWEST

By Professor HAROLD SELLERS COLTON

DIRECTOR OF MUSEUM OF NORTHERN ARIZONA

THE movement of goods from one part of the country to another is an intriguing subject. Economics, religion and esthetics furnished the driving force and transportation a romantic intermediary. As trade plays such a lively part of our own lives we may wonder about trade in the pre-Columbian past. Notwithstanding the fact that study of prehistoric trade demands the most highly technical services of any branch of archeology, yet the archeologist has a considerable fund of information at hand.

However, whenever an archeologist takes up the subject of trade he shortly runs into problems that he himself is unable to solve with archeological techniques, so he must call on some man or woman trained in some other service if he wishes his problem solved. He may need the services of a petrographer, a chemist, a botanist, a zoologist or some other specialist. The progress that has been made in the study of prehistoric trade in the Southwest furnishes a splendid example of cooperation in science.

As the term trade has many meanings, among which the exchange of goods is the most common, perhaps commerce would be a better word than trade, because we can not always prove an exchange of goods. I am, therefore, going to show you some aspects of prehistoric commerce as archeological excavation has outlined it in Arizona, which may or may not include an exchange of goods.

To give you some idea of Indian commerce I will tell you about two historic examples; examples, however, that seem to have their roots in deep antiquity. Until 1880 and the coming of the Atlantic and Pacific Railway, the Indians of northern Arizona were little affected by white men. Although the Apache had dislocated more or less all commerce to the south, yet the east-west commerce across northern Arizona was still much as it had been in prehistoric times and men living to-day have had a part in it.

We will first consider a well-known old trade route which ran from the Pacific Coast in the Los Angeles area to the Rio Grande. This trail in general followed the route of the Santa Fe Railroad or U. S. Highway 66. From the Cajon Pass to the Hopi Towns the trail went north of the railroad because the water holes were closer together. It passed through the country of the Mojave, Walapai and Havasupai Indians. From the Hopi country it turned southeast to Zuni and then east to the Rio Grande near Isleta. Over this thousand miles of trail, shell from the coast passed to points on the plateau and along the route other objects passed east and west. Spier[1] reported how the Walapai Indians killed deer or mountain sheep and traded the hides to the Havasupai, for woven goods procured from the Hopi. The Havasupai in their homes tanned the hide and traded it to the Hopi for woven goods and pottery. The Hopi manufactured the buckskin into white boots for their women or traded the hides or boots to the Zuni or Rio Grande pueblos, receiving in return turquoise from Santo Domingo, Mexican indigo from Isleta and buffalo skins from the plains.

This old trail was in active use in 1776, for Father Garces[2] saw abalone shells from the Pacific Coast, textiles from the Hopi and textiles from the

[1] Leslie Spier, *Anthrop. Papers*, Am. Mus. Nat. Hist., Vol. 39, part 3, 1928, pp. 244–245.

[2] Elliott Coues, "Trail of a Spanish Pioneer," pp. 325–326, New York, 1900.

Spanish at Santa Fe at different points in Western Arizona. He describes a Hopi man and wife on a trading expedition to the Mojave.

This famous old trail is now abandoned, but the trade between these Indian tribes is still quite active, passing over U. S. Highway 66. I have sometimes picked up hitch-hiking Indian traders on the roads. When several years ago, a bus was struck on a grade crossing by a train at Isleta, New Mexico, among the dead was a Santo Domingo man returning from a trading trip to the Hopi. This event was impressed on my mind because he had spent the night before with the Hopis at the Museum at Flagstaff. Indian commerce is not dead.

Probably the most interesting story of aboriginal trade is that of curious red paint, a particularly greasy red ochre, procured by the Havasupai Indians from a cave in the Tonto formation in the Grand Canyon near the mouth of Havasu Creek. This paint is in great demand by the Hopi and other Indians for a face and body paint. It is red, yet has a metallic sheen. The Hopi Indians purchase the paint from the Havasupai for $5.00 a pound, write up the price, and peddle it to other Indians, even as far as the Rio Grande, for 25c a teaspoon. This red paint is considered by the Indians of the Southwest a very superior cosmetic.

This trade in red paint is of long standing and formed the basis of an inquiry called by the Spanish Viceroy of New Spain near El Paso in the year 1691. After the Spanish were expelled from New Mexico by the pueblos who revolted in 1680, the Count of Galve, the Viceroy, wrote a letter to Don Diego De Vargas, then the Governor of New Mexico, who headed a government in exile at El Paso. From Espinosa's[8] translation of this letter I quote the following extracts. The Viceroy wrote:

> From the accounts of persons who have lived there I am told that in the revolted province of New Mexico is located the province of Moqui and that a distance of twelve leagues from there toward the big river (he means the Colorado River) there is a range of mountains one of the most prominent in those parts, in which is found a metallic substance or earth containing vermillion. This is used by the Indians to paint themselves with, and by all the people especially the Spanish women to preserve the complexion. . . .
>
> It is said that the metal is heavier than lead and so liquid and greasy that it goes through the leather pack saddles and pack cloths of the pack animals on which it is carried and that when carried leaves red stains, with the result that it has commonly been held to be quicksilver.

As mercury ore was badly needed in Mexico in the refining of silver and at that time all was imported from Peru or Spain, the finding of mercury ore in New Mexico would be of great economic importance. Therefore the Viceroy ordered Governor De Vargas to interrogate witnesses under oath as to what they knew about it. So an investigation was held at El Paso to which De Vargas called military men, padres and others. During the investigation the witnesses told how this red ore was gathered from a cave west of Oraibi. Although not one of the Spaniards had seen the cave they mentioned friends who had visited it. They confirmed the data in the Viceroy's letter how Hopi traded it to Santa Fe where the Spanish ladies preferred it to all other kinds of rouge. On the strength of this testimony De Vargas was ordered to make an expedition into New Mexico. This he did and reached the Hopi town of Oraibi, where he purchased a burro load of the ore. He sent it on to Mexico City, where it was assayed. It proved not to be an ore of mercury. This little incident shows how old the commerce in Havasupai red ochre is. We have documentary evidence that it was an article of trade before 1680 as it is an article of trade to-day.

I could tell of other modern Indian trade such as funereal and ceremonial garments made by the Hopi and traded

[8] J. M. Espinosa, *New Mexico Hist. Rev.*, 9: 2, 118, April, 1934.

to the Rio Grande, but the cases I have reported will serve as examples as to how Indian trade takes place at the present time and it was probably not very different in the past.

The aim of an archeologist is to outline the history of a people by uncovering the mess that they made when they were alive, their houses, burial ground and their city dumps. By excavation a relative chronology can be built up by stratigraphy and an absolute chronology established by studying the annual rings in timber or charcoal from the ruins. After he straightens out the time sequence he tries to distinguish different cultures in time and space and from these data reconstruct their history.

The archeologist must define the characteristics of the people whose history he is reconstructing. He must study their material culture, that is the objects manufactured by the people, houses, stone implements, pottery and the thousand and one objects used in their daily life. He wants to know the physical build of the people so that he can know to which race they belong. Thus he studies the skeletons from the burial grounds. To know if different tribes or races are contemporary he tries to recognize objects of commerce. To determine the routes of trade he delves in the geography of the country. To recognize centers of population he makes an archeological survey.

In the past many archeologists dug for the purpose of placing objects of art on museum shelves. This aspect of archeology is rather going out of style, but it is still the easiest way to attract money for archeological investigation. Now we want to reconstruct the history and life of a people as far as it is possible to do so, and art is but one aspect.

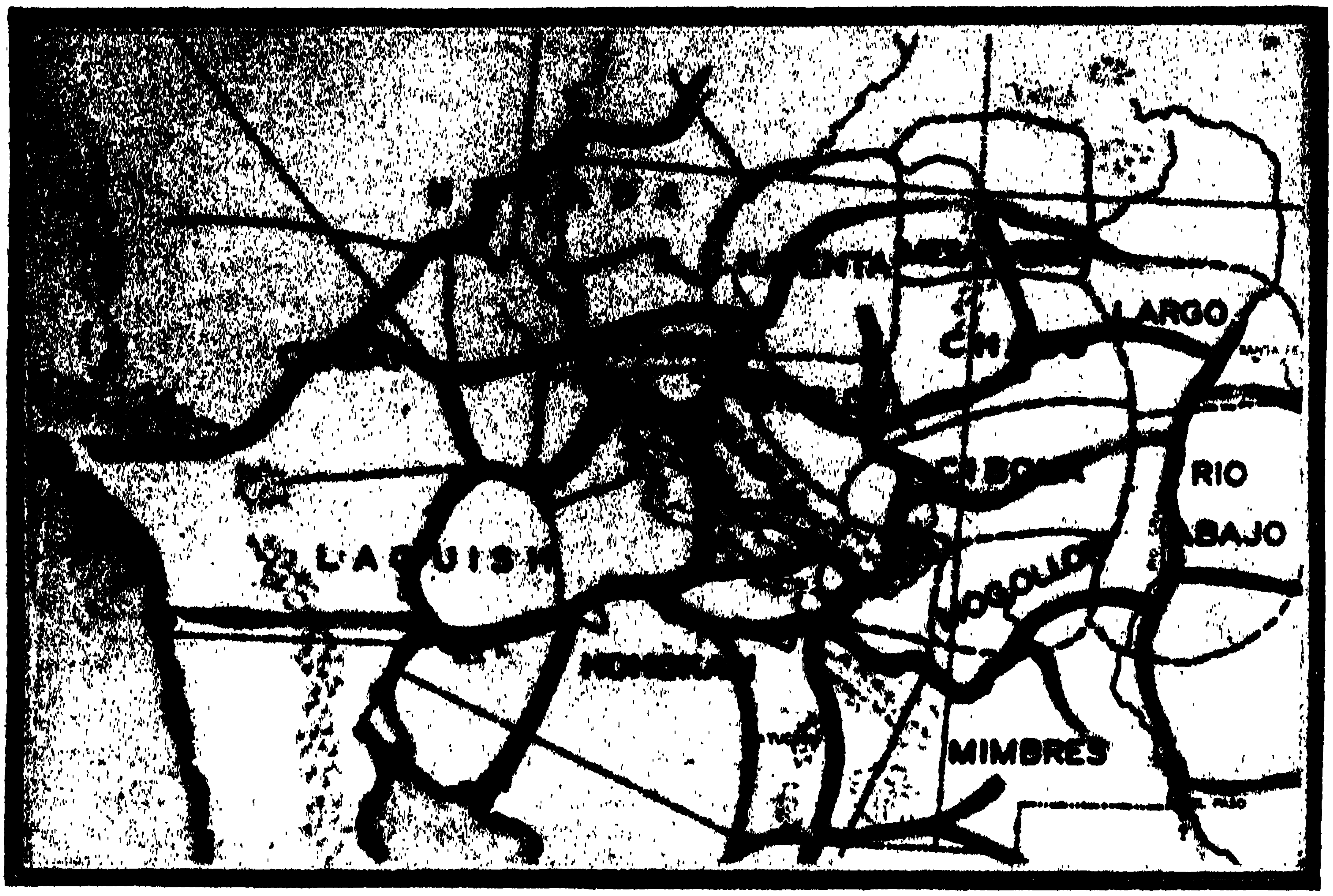
The study of ancient Indian commerce is the most highly technical branch of archeology and requires the services of technically trained investigators in many fields of science. Archeologists themselves can only formulate the problem because all the material has to be accurately identified so that the source can be determined.

Of all the aspects of archeology, a study of Indian objects of trade costs most in dollars and is the most difficult to finance. We must thank those investigators and their institutions for making identifications without charge to the archeologists. If this generous aid were not forthcoming we would know little of aboriginal Indian commerce.

Marine shells form one of the best sources for the study of Indian trade, because marine shells were used for ornaments and are found in prehistoric sites all over Arizona and New Mexico. To determine if they came from the Gulf of Mexico, Gulf of California or the Pacific Coast of California means that they must be identified by a trained malacologist or conchologist, a student of the Mollusca. Boekelmann in New Orleans and Hill at Los Angeles have been rendering this service to archeologists but curators of other east and west coast museums have been giving their valuable time as well.

To determine the source of stone objects and the stone used in pottery for temper requires the services of a petrologist who makes thin sections of the pottery and studies the sections with polarized light, and measures the crystal faces of the minerals. It takes a highly trained man or woman to do this and interpret the results. Dr. Anna Shepard, of the Carnegie Institution, has been preeminent in this field.

To determine the source of some material we must call in the chemist, using ordinary methods of analysis or a spectroscope. An ornithologist, from the bones of birds, must recognize the species, and, from mammal bones, a mammalogist must identify mammals. An ethnobotanist must be called in to determine the source of fibers used in basketry and remains of food plants uncovered from



MAP OF THE SOUTHWESTERN PART OF THE UNITED STATES

SHOWING THE LOCATION OF THE DIFFERENT INDIAN TRIBES CALLED "BRANCHES" AT ABOUT 1100 A.D. THE NAMES OF SOME OF THESE BRANCHES HAVE BEEN SUGGESTED BY GLADWIN, OTHERS BY MERA, ROGERS AND THE AUTHOR. THE MAP ALSO SHOWS THE VARIOUS TRADE ROUTES, PARTLY AFTER BRAND.

the ruins. He can tell the archeologist from what area the plant products were gathered or grown. So you can see that many sciences must be called upon in the study of prehistoric commerce.

Prehistoric commerce may have three phases: Manufactured goods, such as textiles or pottery, may be made in one area and consumed in another. Natural products, such as shells, pipestone, turquoise or salt, may be gathered by the people of one area and consumed by the people of another area. At a red argillite quarry near Del Rio, Arizona, there is a Pueblo ruin which is covered with fragments of the red rock. Evidently the local people quarried the rock and traded it to other places. On the other hand, a consumer might travel a long distance and gather the shell, the salt or the turquoise himself and carry it home. Rogers[4] believes, for example, that the pueblo people may have gone to the Mojave Sink in California to mine turquoise. Expeditions of this sort do not constitute trade in the true sense, for here there was no exchange of goods, so, as the archeologist can not distinguish between them, as I said before, we will call any objects produced in one area and consumed in another commerce or trade.

In prehistoric Indian commerce, we must remember that there were no beasts of burden. Everything had to be carried on the backs of men and only goods of little bulk and high value such as dyes, pigments, fine textiles, ornaments and small attractive pottery vessels constituted this commerce. Necessaries which had bulk, although desired, could not be transported. This was true also of the old world, where overland caravans carried objects of high worth and little bulk, such as silk and spices.

We know nothing about the organiza-

[4] M. R. Harrington and M. J. Rogers, *San Diego Mus. Arch.*, 1: 1, February, 1929.

A HALIOTIS SHELL
THESE SHELLS CAME FROM THE PACIFIC COAST. THE HOLES ARE PLUGGED WITH ASPHALT TO MAKE A BOWL. THIS SPECIMEN WAS EXCAVATED FROM THE RIDGE RUIN NEAR FLAGSTAFF, ARIZONA.

tion of prehistoric Indian trade. Were objects traded from village to village or were trading expeditions organized? We do know, however, that the Southwestern Indians trade as individuals and at times have organized armed bands for the purpose of trade with distant centers. The Aztecs organized such expeditions; the Pima, Hopi and other Southwestern tribes sent out trading parties to visit distant tribes. Bands of Santo Domingo traders often visit the Hopi and Navajo. Hopi traders visit the Zuni or the Rio Grande. We can reason by analogy that the ancient people did the same.

These trading parties were different from the caravans of the old world, where there was a division of labor among the members of the party. In the old world we find a group of traders, with soldiers, camel boys and camp followers. As far as we know in the Southwest every man was for himself, he was the trader, pack animal, and soldier. There was little or no division of labor.

The prehistoric Indians of Arizona had no medium of exchange such as wampum. Their ornaments, shell and turquoise probably served this purpose just as the pueblo Indians and the Navajo use silver jewelry at the present day.

To understand the flow of prehistoric Indian commerce we must recognize and locate on the map prehistoric Indian tribes. These Indian tribes are separated from one another by such traits as one can find in excavation—burial customs, architecture, pottery and other evidences of material culture. As we know nothing of the language and social organization of prehistoric Indian tribes, it is better to follow Gladwin[5] and call prehistoric social units branches. In the Southwest about the year 1100 of our era archeologists recognize something over 21 branches, each one of which we might call a tribe. Between these branches are evidences of commerce of some volume.

In this paper I will frequently mention some prehistoric site in New Mexico and Arizona, so it will be well if I say something of the branch in which they are located. In southern Arizona in our Middle Ages a culture flourished which we call the Hohokam. A site most thoroughly excavated and reported upon by Gila Pueblo is Snaketown.[6]

A culture that flourished south of the San Francisco Peaks in central Arizona we call the Sinagua. Tuzigoot in the Verde Valley, Wupatki, Elden, Turkey Hill, Ridge Ruin belong to this culture. At Winona, 17 miles east of Flagstaff, lies a site which represents a Hohokam migration into north-central Arizona. In northwestern Arizona, the Kayenta branch included such important sites as Batatakin, Inscription House and Kiet Siel. In southwestern Colorado the Mesa Verde Branch includes the important cliff pueblos of the Mesa Verde National Park. The Chaco Branch occupied northwestern New Mexico. Pueblo Bonito and Chettro Ketl are important sites in this culture. Across the Rio Grande, southwest of Santa Fe in New Mexico, the important pueblo of Pecos was excavated by Kidder. The trade

[5] W. and H. S. Gladwin, Medallion Papers, No. 15, 1934.

[6] H. S. Gladwin, E. W. Haury, E. B. Sayles and N. Gladwin, Medallion Papers No. 25, Vol. 1, 1937.

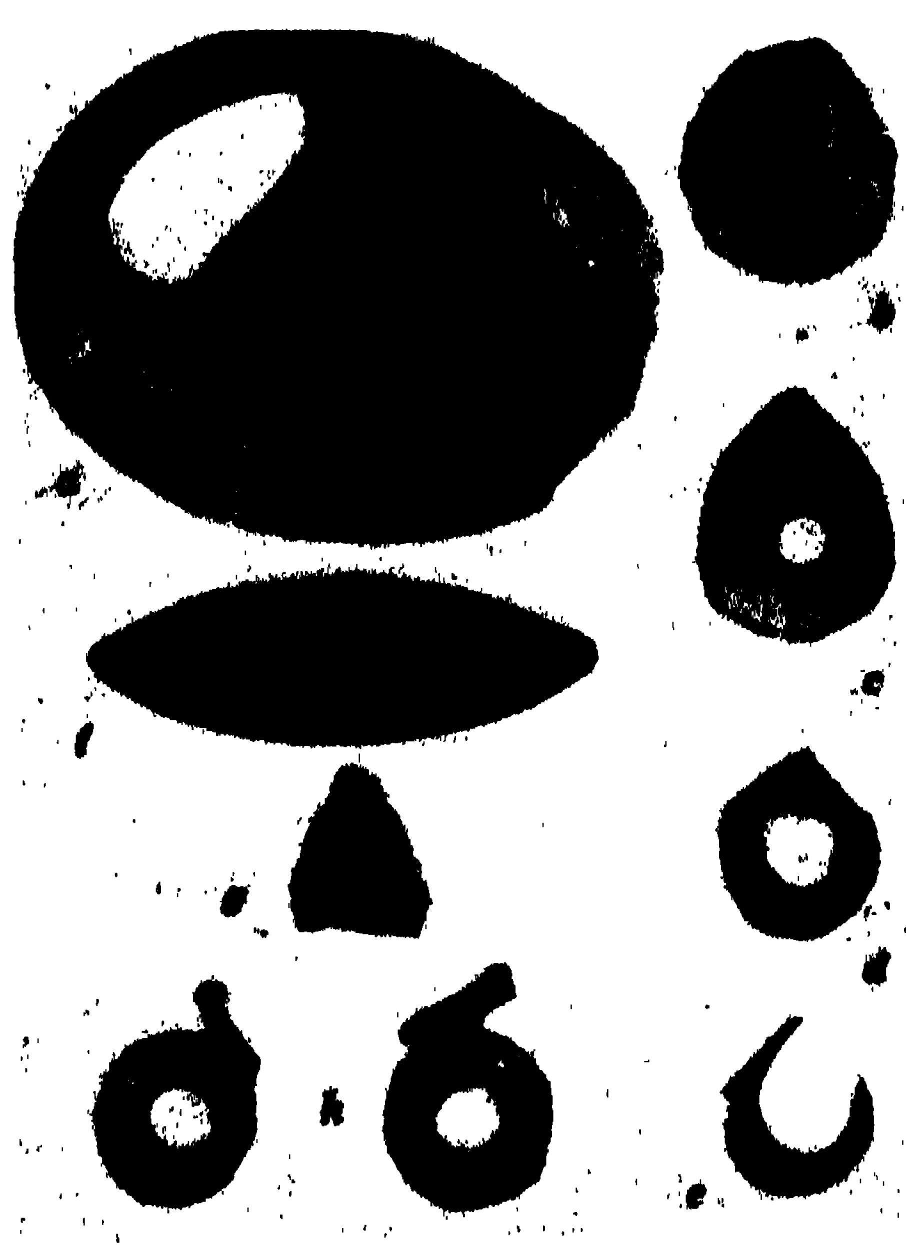
material found in these sites and many others form the substance of this paper.

Fragments of ornaments made from marine shells are found in most sites in the Southwest. All these shells were gathered from the ocean, and so they all represent commerce. Dr. Donald Brand[7] has made an especial study of prehistoric Indian commerce in shell, tracing them from the Gulf of Mexico, Gulf of California and the Pacific Coast to different parts of Arizona, New Mexico, Colorado and Utah. Dr. Brand based his conclusions on the study of reports of archeological excavations. He found that in most reports of archeological excavations the identification of shells was performed in too sketchy a manner to be of much use, but in a number of recent works and a few of the older reports the shells were identified by recognized malacologists. Dr. Brand reported 38 species from the Gulf of California, 9 species from the Pacific coast, 10 species that might have been found either in the Gulf of California or the Pacific coast, and 9 from the Gulf of Mexico; all the latter are found east of the Continental Divide in New Mexico except a couple of doubtful identifications from the Salt River Valley.

Dr. Brand did not have access to the recent work of the Museum of Northern Arizona in the Flagstaff area. On having our shells from the Hopi Country and Flagstaff identified by Boekelmann and by Hill we found we had added seven species to Dr. Brand's list of 66 traded marine shells. Three are found only in the Gulf of California, three are found only on the Pacific Coast, and one is found on both coasts.[8]

From the Pacific Coast the most important shell carried into Arizona and New Mexico was the abalone shell called *Haliotis*. This shell is not found in the Gulf of California, so it forms the best indicator for Pacific Coast trade. It was used for dishes when the holes were plugged with asphalt and small iridescent fragments of abalone mother of pearl were carved and used for ornaments.

The Indians of the coast made fish hooks of abalone shell. First they cut an oval piece out of the center of the shell. Then with a piece of flint they bored a small hole off center. This hole they



FISH HOOKS OF HALIOTIS SHELLS

THIS MANUFACTURE WAS AN IMPORTANT INDUSTRY OF THE PACIFIC COAST INDIANS. (a) HALIOTIS SHELL WITH BLANK CUT OUT WITH THE CHERT FLAKE (g). (b) BLANK CUT FROM THE SHELL. (c) AND (d) BLANKS DRILLED AND REAMED WITH IMPLEMENT (f). (e) A FINISHED FISH HOOK. (h) A PAIR OF EARRINGS FROM THE RIDGE RUIN NEAR FLAGSTAFF, ARIZONA, WHICH ARE OBVIOUSLY MADE OF HALIOTIS SHELL FISH HOOK BLANKS WHICH HAD BEEN TRADED INTO NORTHERN ARIZONA. THE PHOTOGRAPHS OF THE STAGES IN MANUFACTURE WERE FURNISHED THROUGH THE COURTESY OF ARTHUR WOODWARD OF THE LOS ANGELES MUSEUM.

[7] Donald D. Brand, Year Book of Pacific Coast Geographers, Vol. 4, p. 3, 1938.

[8] The following shells, excavated near Flagstaff, are not mentioned in Brand, 1938. From Gulf of California: *Nassarius versicolor, Turritella goniostoma* and *Glycimeris tesselata*. From Pacific Coast: *Haliotis corrugata*. From Gulf of California or Pacific Coast: *Panope generosa solida, Dentalium neohexigonium* and *Dentalium semipolitium*.

GLYCIMERIS SHELL AND RING

GLYCIMERIS SHELL, LEFT, WHICH IS ONLY FOUND IN THE GULF OF CALIFORNIA. RING, RIGHT, MADE FROM A GLYCIMERIS SHELL BUT FOUND AT WUPATKI, A PREHISTORIC RUIN NEAR FLAGSTAFF.

enlarged by grinding with a conical stone. When a hook was needed, the Indian took a blank and cut away the shell, making a hook. When Arthur Woodward of the Los Angeles Museum saw some ornaments, a pair of earrings that we found in the Ridge Ruin, he pointed out to us that they were made out of West Coast fish-hook blanks. It is not in many parts of the world that earrings are made out of fish hooks.

Glycimeris shells, which are bivalves, were gathered on the beaches of the Gulf of California and the centers cut out before transportation. Woodward[9] has found sites of this industry in Sonora, where the circular discards cut from the shell were left on shell heaps. In that way the trader had less weight to carry when he set out on his long tramp to the Hohokam Villages in the Gila Basin.

Small conus shells had the spire ground off and were used as tinklers. The present-day Indians of the plateau make similarly shaped tinklers of tin. Olivella and nassarius were made into beads as well as pelecypod fragments.

Most of the shells found about Flagstaff, at Snaketown and Tuzigoot were derived from the Gulf of California. Yet others came from the Pacific Coast. It is evident, as Haury[10] suggests, that the Hohokam area must have been the commercial distribution center for much of this trade in the Southwest.

Stone such as diorite for axes, soapstone, red argillite, and turquoise for ornaments and malachite, cinnabar, and hematite for paint were widely traded, but much exploration in rough difficult country is needed before the exact sources of all the materials are located.

In the excavation of a pit house in Picture Canyon, 6 miles east of Flagstaff, the author once unearthed a cache of six unused three-quarter grooved axes of diorite, which were buried in the debris on the floor of an abandoned pit house, probably by a trader who never returned to recover them. This diorite must have come from Southern Arizona and possibly even from Sonora, where Woodward[11] reported green diorite implements in abundance in the Altar district.

At Ridge Ruin were found some small soapstone (steatite) ornaments. Steatite is not found in the plateau but is found in the mountains of the Gila River Valley, as reported by Haury.[12]

One sometimes finds large buttons of lignite in the excavations. We would look for the source of this material in the various Mesozoic coal measures which cover certain areas of the plateau from Kayenta and Oraibi to Gallup or near Santa Fe. When found at Flagstaff, it is certainly an object of trade whatever the exact source may be.

At Tuzigoot, Ridge Ruin and at other sites small ornaments such as nose plugs, lip plugs and the small images of animals and birds have been found made of red argillite.

Two years ago we located a prehistoric quarry of red argillite in the Mazatzal Quartzite, a Pre-Cambrian rock, near Del Rio in Yavapai County, Arizona. The ornaments from the sites and the material from the quarry have been analyzed by the spectroscope by David E. Howell[13]

[9] Arthur Woodward, *Am. Antiquity*, 2: 2, 117, October, 1936.

[10] E. W. Haury, Medallion Papers No. 25, 1937.

[11] Arthur Woodward, *op. cit.*, p. 120, 1936.

[12] E. W. Haury, *op. cit.*, p. 129, 130, 1937.

[13] David Howell, Ms.

and have been found to be identical. Near the quarry lies a medium-sized pueblo, among the ruins of which are found thousands of fragments of argillite. This material was probably traded into the Verde and from there over the Southwest.

Copper bells made by the *cire perdu* (lost wax) method have been found in excavating in New Mexico and Arizona. As was pointed out by Gladwin, the casting of these bells in copper by the *cire perdu* method by primitive people involves a high degree of technical knowledge and skill. Forty of these bells have been chemically analyzed by spectroscopic methods by William C. Root, of Bowdoin College, Maine. He reported that the copper bells from the Southwest were not made of copper from the plateau of Mexico or from Lake Superior Region, and Haury suggests that they were either made in the Hohokam area of southern Arizona or in northern Mexico.[14] Four of the ten bells found in the Flagstaff area have been analyzed by Dr. Root. He found the composition similar to 40 other bells from Arizona and New Mexico. As they could not have been made in the Flagstaff area they represent trade from southern Arizona up the Verde trail.

Animal remains in the ruins are quite common and are important to record with great accuracy not only because they give clues to the environment of the people but also because they show trade relations. Parrot remains were not reported from Snaketown, but a number have been found at Wupatki near Flagstaff, at Tuzigoot, and Pepper (1920, p. 194) found 14 in a room in Pueblo Bonito. These parrots from the Flagstaff area have been identified by Dr. Alexander Wetmore as *Ara militaris mexicana*, Mexican green macaw, and *Ara macao*, the red, blue and yellow macaw. The habitat of the green macaw lies in tropical Mexico and now extends north as far as the Yaqui River in Sonora. The habitat of the red, blue and yellow macaw lies in South America, but its range now extends along the east coast of Mexico as far north as Tampico. Fewkes[15] described a desiccated macaw from a burial at Wupatki near Flagstaff, with the feathers still on it, and the Museum of Northern Arizona discovered the remains of several other macaws that had been carefully interred. It seems evident that the birds were valuable and were traded up to northern Arizona from Mexico alive. Even if the ranges of these birds extended farther north 700 years ago than now, this trade represents fairly rapid transportation over a very long route.

From the excavation of the Ridge Ruin were recovered a number of objects, mostly turquoise mosaics mounted on some sort of a plastic. Among the objects was a wooden wand with a plastic head inlaid with turquoise mosaic. A glycimeris shell bracelet had a sheet of plastic attached by a lug protruding through a hole in the shell and on this sheet a turquoise mosaic was set. This same plastic was found in balls on certain sticks and in granular form. This

MACAW SKULL

SKULL OF THE RED, BLUE AND YELLOW MACAW, ARA MACAO, A PARROT FOUND IN THE TROPICAL PART OF THE EAST COAST OF MEXICO. THE SKULL WAS FOUND AT WUPATKI, NEAR FLAGSTAFF.

[14] W. C. Root, Medallion Papers, No. 25, 1937, p. 276.

[15] J. W. Fewkes, "Two Summers' Work in Pueblo Ruins." BAE 22nd An. Rept. 1904, Pt. 1, p. 50.

material was sent to Dr. Volney Jones, of the University of Michigan, for identification, who reported it as lac, the secretion of certain scale insects that inhabit the creosote bush (*Larrea*) and some other desert plants. At present the lac insect is quite scarce in southern Arizona but is found in some abundance on the creosote bushes in western Arizona near Kingman. Lac is an alcohol soluble resin identical to shellac from India, which is the basis of our shellac and sealing wax.

Lac was probably prepared by scraping insects off the branches of creosote bushes. We found in the ruin a quantity of the untreated lac secretions just as they were scraped off the bush. This crude lac was probably melted and stirred with sticks, for we found sticks with balls of lac in the excavation. It was then molded into thin sheets of different shapes which were decorated by imbedding turquoise or other fragments in the surface. When hot the lac can be molded in any form and is a convenient plastic for the manufacturing of many small objects, on which turquoise fragments can be imbedded. The Indians of the Colorado basin at the present time use lac for many purposes, to waterproof their baskets, patch cracks in their water jars, and for balls used in games. Now that lac has been recognized from a prehistoric site it will probably be discovered in other collections of material from the Southwest.

The presence of lac in some abundance in a burial at the Ridge Ruin, a site near Flagstaff, indicates trade probably from the Colorado Valley. Although lac is found in the Gila-Salt area and in the Grand Canyon, it is less abundant than in the area around Kingman, Arizona, and so harder to collect.

My own interest in prehistoric trade lies in the field of pottery, because pottery remains are so well preserved in prehistoric sites and are so abundant that the volume of trade can be indicated. Copper bells, parrot remains, argillite and turquoise ornaments are rather rare, so rare that their contribution to commerce was rather small unless the ornaments represent a medium of exchange. However, the volume of pottery traded was enormous.

To distinguish traded pottery from the indigenous pottery requires a study of the pottery of the whole Southwest. This means that we must have accurate descriptions of types, covering methods of manufacture, structure of the core, kind of temper, surface treatment and styles of decoration. As almost four hundred pottery types are recognized in the Southwest, no one can carry the details of all these in his head, therefore, whether we like it or not, some method of classification is necessary. Then again some archeologists have been very careless in the identification of the types that they have described, renaming types that have already been named, or describing types so loosely that comparisons are impossible, so many types bear several names. A number of types have as many as five names. So my efforts first have been to recognize synonyms, second to classify the types into larger groups called wares, and third to determine the region in which each type was manufactured. I have begun, so to speak, at home in the San Francisco Mountains and have slowly spread out into other areas. I feel I have only made a beginning, but other workers in the Southwest have cooperated, so in a few years our foundation will be much more secure than it is at present.

I wish to particularly urge archeologists not only to have their types carefully identified, but to save large samples of each type from a site so that they can be re-examined a few years later as new technical methods are made available. It is the custom of archeologists, after a study has been completed, to scrap all sherds, so it is forever impossible to determine the source of trade pottery by future methods of analysis.

For the determination of the home

town of a piece of pottery we have to examine a broken surface. Museums will not let us break pieces out of their treasured whole vessels, so we must study sherds. The best determiner of an indigenous type—by that we mean pottery made on or near a site—is the utility vessel, a storage or cook pot. These are usually large and hard to transport, so the fragments are apt to be found close to the place of manufacture, and, if transported as they sometimes were, their fragments form but a small proportion of the sherds in the new area.

Most prehistoric Indians made, besides their large storage and cooking pots, small bowls and jars in which food was served. On these the potter gave loving care and they show the finest results of the arts and crafts of a people, but these small bowls were so widely traded that it is difficult sometimes to locate their home tribe. As these vessels were used in serving food, we will call them "service types."

It is most important to determine the place of origin of attractive "service types" which were small in size and widely traded, and it is not always an easy thing to do this. A criterion often used by archeologists is local abundance, but this is not a safe guide, particularly if the vessels were found in burials because valuable exotic objects were selected for burial offerings. A type called Jeddito Black-on-yellow is a service type made from 1300 to 1500 A.D. of Hopi clay in the Hopi country. The clay is similar to the clay used in the manufacture of storage and cooking vessels from the Hopi country, except that little or no sand was used for the temper. Jeddito Black-on-yellow was so abundant in burials in certain sites in the Verde Valley and Tonto Basin that some archeologists have considered a Hopi migration into those areas in the 1300's. However, as the corresponding cooking and storage vessels were not found with them I suspect trade, particularly as chemists have shown that the clay in those vessels was not local but was similar to Hopi clay.

Between 700 to 1300 A.D. the women of the Kayenta Branch in northern Arizona made small bowls of black-on-white pottery and corrugated cook pots. Fragments of their black-on-white bowls are found in almost every excavated site in the Salt River Valley and whole pieces in some. As the style of design changed over a period of years and these designs have been dated by the tree ring method thus have the Salt River Valley Ruins been dated. Excavations at Chaco Canyon, New Mexico, have uncovered Kayenta pottery. It has been found as far west as the Mojave Desert. All this points to widespread traffic.

In the San Francisco Mountain black sand area the people made brown storage jars of basalt residual clay with crushed volcanic tuff temper, also small bowls of red with a black burnished interior with basalt sand temper, and red bowls with a black painted design or a polychrome pottery, using volcanic tuff temper. Like the Kayenta pottery these latter attractively painted bowls were widely traded to the major contemporary branches. But the red bowls with a burnished interior called Sunset Red were not so popular, and fragments are rarely found far outside the black sand area.

The red on buff pottery of southern Arizona was little traded to the North, only a fraction of the amount of sherds being found compared out of its environment compared to the amount of northern sherds found in southern sites. Since there was little reciprocal trade in pottery it means that to balance the northern pottery traveling south objects other than pottery were carried north, which was, perhaps, shell and textiles.

I think we can safely say that every Indian tribe in the Southwest that made pottery made a "utility type" for cooking and storage and one or more "ser-

vice types" for serving food. Although the finishing of these two types was often quite different yet they were alike in certain basic techniques of manufacture. Their clays were usually from the same general source, the temper was usually the same except for size, they were fired in the same kind of atmosphere, oxidizing or reducing and constructed by the same methods, coils obliterated by the use of paddle and anvil or coils obliterated by scraping with a piece of sherd or gourd. To settle these finer points the archeologist has often to call in the ceramic technologist, the geologist and the chemist.

Although individuals on foot may traverse Arizona and New Mexico from one point to another from in almost any direction, yet the bulk of the movement would follow certain lines of geographical least resistance. Knowing the centers of population, topography of the country, the source of trade objects, position of water holes and historic Indian trails, we can approximate the principal routes of commerce over the Southwest. Men will go around a rough mountain range, all things being equal; but in a desert region will cross the mountains if they provide water on the way. Across the Mojave desert the Indian trails went from a water hole in one mountain range to a water hole in another mountain range. If you know where to look, water can be found in the mountains every twelve miles or so on his route across the Mojave desert.[16] As the present highway and the railroad avoid the mountains their routes were impossible in prehistoric times.

River valleys with living streams form natural avenues of trade. They supplied water, stopping places in villages and an easy way if the way led in the right direction, so important trade routes must have followed the Gila, Salt, Verde, Santa Cruz, Little Colorado, Puerco and Moenkopi Vallies in Arizona and the Rio Grande, Puerco and San Juan in New Mexico.

(1) Three main routes can be traced from the Pacific Coast. (a) From the region of San Diego up the Gila through the country of the Hohokam to the Rio Grande, as shown by Brand and Haury.[17,18] (b) From the region of Los Angeles to the Colorado near Needles and on to the plateau following the Little Colorado tributaries and the San Juan into New Mexico. (c) Another route from the Los Angeles area passed north of Boulder Dam to the Virgin Valley sites and other Utah points.

(2) One or more routes led from the Gulf of California to the country of the Hohokam.

(3) From the Hohokam to the Plateau two main routes are indicated. (a) Up the Verde to the Sinagua and Kayenta, and (b) up the Salt to the White Mountains and Cibola Branch. Minor routes led into the most remote areas.

(4) Brand[19] shows three main routes from the Gulf of Mexico into New Mexico, following the rivers Rio Grande, Canadian and Brazos.

So far I have been talking about prehistoric trade during the eleventh to fourteenth century. You may ask, "What of earlier trade?" Gurnsey[20] found in the Basket Maker II caves of northern Arizona whose date might be placed 300–500 A.D., only Pacific coast marine shells, abalone and olivella. In general, shells are relatively rare in the early periods. In Basket Maker III (500–700 A.D.) shells are scarce, but as both glycimeris and abalone are reported we have indications of trade from the Gulf of California as well as the Pacific Coast. In Pueblo I (700–900) in the

[16] Whipple, "Water Holes in Mohavi Desert." 1858. BAE 26th An. Rept. 1908, p. 92.

[17] Brand, *op. cit.*, p. 7.

[18] Haury, *op. cit.*

[19] Brand, *op. cit.*, p. 9.

[20] Guernsey, "Explorations in Northeastern Arizona." Papers of Peabody Museum, Harvard University, Vol. XII, No. 1, p. 68, 117.

San Juan area shell shows trade from both sources. From 800 to 1000 A.D. in the Flagstaff area, shells are scarce, but three species are found that live in the Gulf of California, but none have been reported upon from the Pacific Coast.

In the excavations in southern Arizona in the Grew Site and at Snaketown, pottery is found that was made before 700 A.D. north of the Little Colorado. Plateau types made before 1100 A.D. are found in the desert mountains of northwest Arizona.

In general, we may say that some trade took place in the earliest periods that have been reported upon in Arizona, but that from 1000 A.D. on trade was in a much greater volume than in the earlier periods.

As to mediums of exchange, we have little to say. It is conceivable that the prehistoric people made attractive pottery, especially for exchange, just as the Hopi do to-day. Indeed, the modern Indians use jewelry when they have no cash, but there is no evidence that the Indians of Arizona either in ancient or modern times used shell as the Indians of the East used "wampum" as a medium of exchange with a fixed value. In the Southwest bead necklaces are valued somewhat on the number of beads, but other factors enter into the transaction such as quality and artistic arrangement.

Modern Indians have rates of exchange for goods which fluctuate within narrow limits. Among the Pima, Russell[21] states a gourd equals a basket in trade; a shell necklace, a metate; a basket, a blanket; and a string of blue glass beads, a horse; a string of blue glass four yards long, a bag of paint.

Spier[22] reports, among the Havasupai in the period 1840–65, a tray of shelled corn equals a Navajo saddle blanket; the biggest burden basket of shelled corn, a horse; big blanket, a gun; ten buckskins, a race horse. I do not suppose it was more difficult to remember the trade value of their few objects than for us to know the value of our goods in dollars and cents.

You may wonder how far various objects have traveled in prehistoric trade. From the reports of archeological digs we find that pottery travels rarely more than 200 miles, yet other objects can be proved to have traveled much longer distances. Kidder[23] found Gulf of Mexico marine shells at Pecos that must have traveled a distance whose bee line is over 700 miles. He found shells from the Pacific Coast that had traveled almost as far. Some of the parrots, red-blue-yellow macaw, found at Wupatki, must have been carried 1,200 miles, but the longest distance recorded is a vessel found by Pepper[24] at Pueblo Bonito in Chaco Canyon, New Mexico, which might have come from the valley of Mexico 1,300 miles away.

The study of aboriginal trade has just begun. The centers of the manufacture of a few objects have been proved above any reasonable doubt. Although we see dimly some of the broad aspects of aboriginal trade we need the aid of the specialist to help us settle the source of manufacture of many objects. We have made a beginning, but thanks to the gracious cooperation among scientific men, the possibility of further contribution to this study of prehistoric commerce appears to have no limit to its horizon.

21 Frank Russell, "The Pima Indians."

22 Leslie Spier, *op. cit.*, p. 245.

23 A. V. Kidder, "Artifacts of Pecos," p. 188, 1932.

24 G. H. Pepper, *Anthrop. Papers*, Am. Mus. Nat. Hist., Vol. 27, 1920, p. 208.

A PREFACE TO SOLAR RESEARCH

By Dr. DONALD H. MENZEL
HARVARD COLLEGE OBSERVATORY

THERE are many reasons why study of the sun is one of the most important fields in science. The sun is the nearest star, the only one we can examine in detail. It thus provides a test and check on theories of stellar astrophysics in general. As the center of the solar system, the sun furnishes light, heat and energy to the earth, as well as to the other planets. It is an important factor in controlling the weather. It is the source of the electrification of the ionosphere. Magnetic storms, radio fade-outs and aurorae are clearly connected in some hidden way with sun-spots or, more precisely, with solar variation.

The sun is important for the physicist and physical chemist, as well as for the astronomer. Through the medium of spectroscopic analysis, they gain information about atoms and molecules of the solar atmosphere and learn about the behavior of the elements under conditions of excitation that can not be reproduced in the terrestrial laboratory. Thus they may extend the existing experimental data and check calculations on the behavior and break-down of atoms and molecules. Study of the solar spectrum may well provide new methods for improving the accuracy of spectrochemical analysis.

It is easy to see why numerous observatories have devoted considerable attention to the securing of observations of solar phenomena. The details of the surface layers are of interest in themselves: sun-spots, granulation, faculae, flocculi, chromosphere, prominences and corona. In the United States, observational programs are being carried out chiefly at Mt. Wilson Observatory, at the McMath-Hulbert Observatory of the University of Michigan, and at the newly established Fremont Pass Station of Harvard Observatory, Climax, Colorado. Certain special phases of solar work are being pursued elsewhere, *e.g.*, at the Smithsonian Institution, the McDonald Observatory, and the Yerkes Observatory. The theoretical and interpretive work has been pursued mainly at Mt. Wilson and Harvard.

THE PROBLEM OF INTERPRETATION

Despite the large amount of observational data that has accumulated at various institutions all over the world, progress in the interpretation of solar phenomena has been slow. Our failure to advance has, undoubtedly, been largely due to the inherent complexity of solar phenomena. The nature of the problems is apparent, however, even though their solution seems remote. Can we, at the present point, by taking stock of the existing data and experimental equipment, devise new procedures that will speed the progress of solar science? Are we making full use of the knowledge and techniques of physics and industry?

One of the first points that meets the eye in a preliminary general survey is that theoretical discussion has somehow lagged far behind observation. Experience with other sciences shows clearly that progress is most rapid when theory and observation keep nearly in step, neither outdistancing the other at any time. At least part of the difficulty in the solar problem is that interpretation and theory are often purely physical matters. And few astronomers, unfortunately, are also theoretical physicists, with appropriate knowledge of atomic spectra, statistical mechanics, wave me-

chanics, hydrodynamics, radiation and electromagnetic theory.

Clearly, all the above fields are significant in the interpretation of solar observations. Likewise, the physicist, who might be capable of contributing, is unfamiliar with both the problems and the observational data. The few theoretical advances that have been made are chiefly of a mathematical nature and, as such, often fail to conform either to physics or to the facts of observation. The resulting theories, in consequence, lack plausibility.

Let us examine a few of the outstanding problems of solar astrophysics, and try to see what new observational data are needed, how they may possibly be secured, and where new techniques or theory may be applied. This outline represents a bare beginning of inquiry into solar problems and omits many important phases, including that of the solar interior.

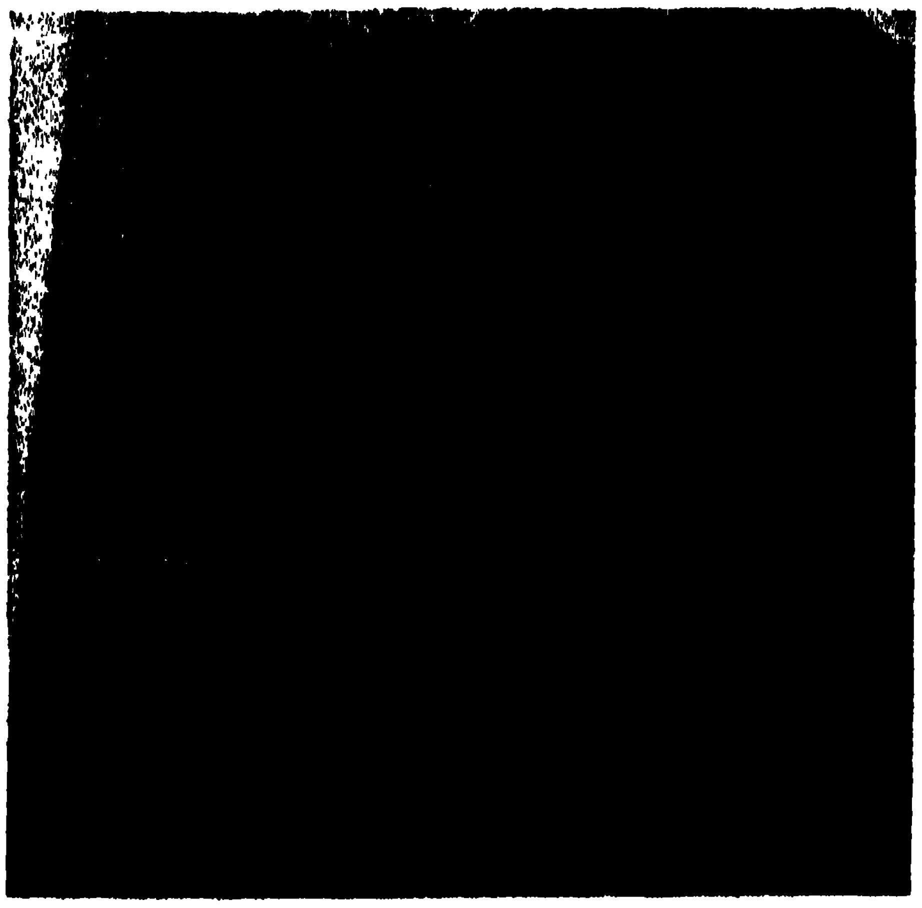
SUN-SPOTS ARE VORTICES

First, consider the question of sun-spots. The direct conclusion from the observational data is that sun-spots are storm areas of a cyclonic nature in the solar atmosphere. They are regions of low pressure, and their darkness is evidently caused by the cooling of the gases expanding into the affected area. The spectra of spots exhibit less excitation than do those of the normal solar surface, in the form of more intense low-temperature lines of neutral metals. Molecular bands, also, are present, showing that the temperature is low enough to permit the formation of elementary chemical compounds. The atomic lines are split and display polarization phenomena characteristic of an intense magnetic field.

It is believed that sun-spots are vortices. In fact, the mere presence of a strong magnetic field is an almost unrefutable argument for the existence of at least an electric vortex or solenoid. But very little is known of the rate of the vortex rotation or of the law that the velocities follow, outward from the vortex center. There seems to be a chance to determine this velocity from observation alone. Most spectroheliograms are

THE FLASH SPECTRUM

A SECTION FROM ONE OF THE FLASH SPECTRA OBTAINED BY THE HARVARD-MASSACHUSETTS INSTITUTE OF TECHNOLOGY ECLIPSE EXPEDITION TO SIBERIA, JUNE 19, 1936. THE COMPLETE CIRCLE NEAR THE RIGHT OF THE PICTURE IS THE CORONAL RING, RECORDED IN THE GREEN LINE OF "CORONIUM." ITS ORIGIN IS STILL UNKNOWN. NOTE THE "CORONAL PROMINENCES." THE BRIGHT LINES AT THE CENTER ARE THOSE OF MAGNESIUM.



Yerkes Observatory.

SOLAR GRANULATION

THE SOLAR DISK, AS SHOWN IN THIS PHOTOGRAPH, IS FAR FROM UNIFORM. THE BRIGHTER AREAS CONSIST OF MYRIADS OF TINY GRANULES, IN A STATE OF RAPID ACTIVITY.

indecisive on this point, either showing no rotation at all or indicating a direction of spin quite different from that required by the magnetic field. A few spectroheliograms that have been made public exhibit the phenomenon of a prominence's apparently being sucked into a vortex. The filaments become more and more curved as they approach the center, which suggests conservation of angular momentum. Measurements of the curvature and the drift of the filaments should give important data concerning the nature of the vortex; at least they will yield information about the effect of the vortex at high chromospheric altitudes. Studies, with motion-picture cameras, of the spots themselves, particularly of the penumbral filaments, should give additional information about sun-spot circulation.

Spots as Giant Electromagnets; A Million Million Amperes

Upon the observational data of this vortex rotation depends the future development of the theories of sun-spot magnetism. The gases that comprise the solar atmosphere are highly ionized, broken up by the action of radiation and high temperature into electrons and ions. It was once thought that mere rotation of the ionized gas would set up a powerful field. But further examination proves that a rotating mass of gas, however highly ionized, will not give a magnetic field if it contains an equal percentage of ions and electrons. For the positive pole produced by rotating charges of one sign is just cancelled by the negative pole formed by the whirling charges of opposite sign. Nor can there be a sufficient excess of protons or electrons to give the field, because a sun-spot so highly charged would break up instantaneously and explosively in the powerful electric field.

It appears that the magnetic field results from a galvanic current produced by actual slipping of charges of one sign with respect to those of the other. The real question is how the enormous currents, which must be of the order of a million million amperes, are set up and maintained. They are probably automatically produced inside any vortex of ionized gas. The exact details of the process are still obscure, but there is hope of solving the problem if only such significant data as the law of vortex rotation can be determined observationally.

The fields probably arise from differences in relative freedom to move of charges of opposite sign. The free negative electrons, extremely light, are easily deflected by collisions with other atoms. Further, they react very rapidly to the existence of even a small magnetic field, moving in small circles, whereas the positive ions move in large ones. A preliminary analysis by Dr. T. E. Sterne and myself is promising in this connection; it shows that we may well expect the electrons to drift relative to the ions. Further analysis, however, is held up by lack of observational data on spot motions as well as by a dearth of knowledge of electron-atom collisions. The latter

information must come from physical studies of the properties of matter.

WHAT IS THE SHAPE OF A SUN-SPOT?

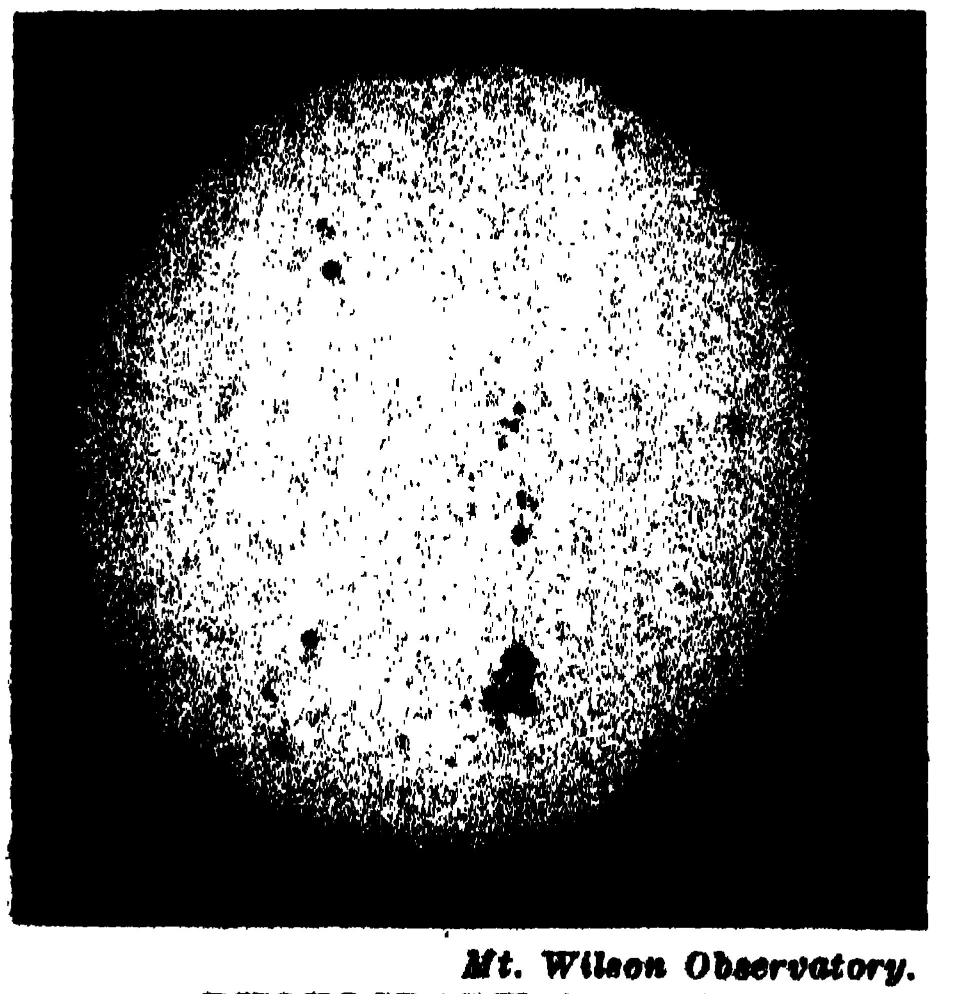
Associated with the vortical motion of sun-spots is the "pumping" action, which draws material up from the heated interior, cools it by expansion, and then allows it to descend. The maintenance of this circulation over long periods of time presents a major problem of sun-spot activity. From theoretical investigations of the circulational features involved, we should be able to decide whether a sun-spot is long compared with its cross-section, like a terrestrial tornado, or whether it is flat, like a whirlpool in a shallow basin. Both concepts have been urged by some astronomers, but the vortex character lends favor to the former view. What, also, is the size of the true vortex, as distinguished from the rotating mass of gas surrounding the spot center, but which is not a true vortex in the strictest meaning of the word? These problems are all allied with the important question of the distribution of temperature and pressure in the vortex. These quantities are not directly observable, but they should be calculable if the true nature of spot structure can be ascertained. Quantitative measures of the intensities of spectral lines in spots should be of assistance to the astronomer in determining the physical conditions within the spot.

SUN-SPOT TWINS

Next there is the problem of associated sun-spots, pairs and groups being far more common than single ones. Since a vortex must, on simple hydrodynamical theory, possess two ends, each lying in a surface of the medium (or extending to infinity), the well-known "bi-polar" character of doubled spots seems significant. The opposite ends of a single vortex must be right- and left-handed, and the fact that one spot of a pair invariably possesses a pole of sign opposite to that of the other, is strong evidence in favor of the vortex relationship. Even when the second spot is not visible, or perhaps merely indicated by a facular disturbance, it may make itself known through the presence of its magnetic field, which splits the lines of the spectrum. We should like to know more about these invisible spots.

THE SUN ROTATES FASTER AT THE EQUATOR

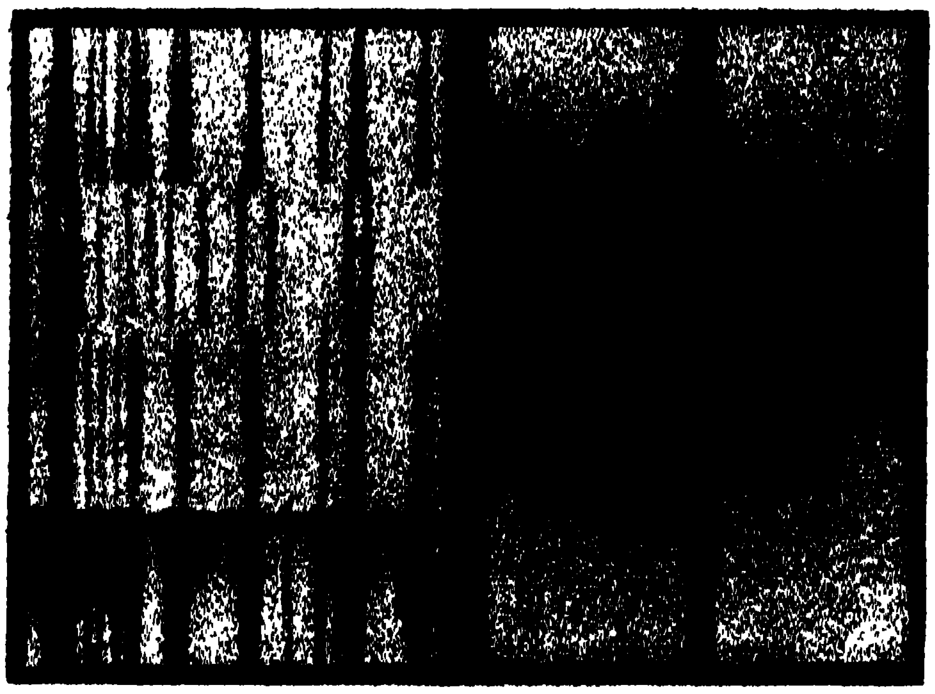
The so-called "equatorial acceleration" of the sun is exhibited by the simple fact that sun-spots near the equator complete a circuit in shorter periods than those nearer the poles. The problem of the maintenance of the drift in the presence of opposing drag of neighboring layers must be studied. It is important to note that mere transport of material from one solar latitude to another should produce quite the opposite effect, as in the terrestrial trade winds. Thus the source of the acceleration is probably very deep-seated, perhaps in a core that rotates much more rapidly than the solar external layers.



Mt. Wilson Observatory.

PHOTOGRAPH OF SUN

NEAR SUN-SPOT MAXIMUM; AUGUST 12, 1917. NOTE, IN ADDITION TO THE SPOT, THE BRIGHT FACULAE WHICH ARE MOST CONSPICUOUS NEAR THE SUN'S EAST AND WEST LIMBS.



Mt. Wilson Observatory.

THE ZEEMAN EFFECT

THE SPLITTING OF SPECTRAL LINES UNDER THE INFLUENCE OF A MAGNETIC FIELD IS CLEARLY SHOWN IN THE LEFT-HAND PHOTOGRAPH. THE ANALOGOUS SPLITTING IN THE SPECTRUM OF THE SUN-SPOT IS SHOWN IN THE RIGHT-HAND RECORD.

Whether we can discover the origin or not of the eastward equatorial current, its mere existence presents numerous unsolved problems connected with sun-spots themselves. A sun-spot pair, with the members in slightly different latitudes, is subjected to an enormous shearing force. The surprising feature is that it does not tend to disrupt spots more seriously. Even a single spot is subject to this peculiar force. In only a day or so a circular spot located in the regions of greatest shear would be markedly distorted into the form of an ellipse, if the sun-spot forces did not oppose the effect caused by relative drift of gases in neighboring latitudes. No evidence of such a distortion now exists, but careful observations might disclose an effect. Such data are important, as indeed are the relative motions of spot members, for they will give information about the fundamental character of the vortices. Theoretically, the filaments of neighboring vortices should interact to produce relative motions.

The Sun's Double Vortex

Finally, there is the question of all the spot groups taken together. Why do spots appear only in the zones between the 40-degree latitude parallels of the solar surface and never in the polar regions? Thus enters the very complex problem of solar variation, as exhibited by sun-spot phenomena. Not only do the numbers show the well-known rise and decline with the eleven-year cycle; there is also the equator-ward drift of the sun-spot zones, as the cycle progresses. We see in this behavior and in the longevity of various spot groups evidence for powerful vortical currents that persist for long periods of time. A full appreciation of the nature of this deep-seated circulation is important if progress is to be made in the problem of sun-spots and solar variability. The opposite magnetic polarities of the preceding and following spots in the northern and southern hemispheres and their reversal at the next cycle shows that the time period is one of 23 years.

The large-scale motion of spots is suggestive indeed that we are dealing with a vortex within a vortex, *i.e.*, a double set of coupled vortices. One governs the formation of individual spots, and the second the cyclic periodicity of spots as a whole. Bjerknes has given an elementary hydrodynamic theory, which is capable of being further developed. It is tempting indeed to suggest that the general magnetic field of the sun is associated with the second type of vortex in the same way that the fields of individual spots are produced by vortices of the first variety. Further studies of this general magnetic field are urgently needed.

Needed Observations

It is apparent that the present program of sun-spot observations is sufficient in certain respects. Through cooperative effort of many observatories in various parts of the world, a regular record is kept of the spottiness of the sun and of the growth and development of groups. Thus the more general features of the problem of spot variations are well

covered. But the foregoing discussion clearly shows the need of more detailed analysis of individual spots and their fluctuations from minute to minute and hour to hour.

The old-fashioned visual solar observers, like Young, Secchi, Langley and Lockyer, have unfortunately almost completely disappeared. They recorded the interesting and peculiar behaviors of individual spots. Visual observers, however, are always at some disadvantage. The changes in spots, though significant in the course of hours, are so slow that the eye may fail to perceive important variations or may misinterpret the others. And, unless the astronomer is also a skilled artist, which is rarely the case, the mere written records fail to do justice to the observations.

Even the ordinary series of photographs often presents difficulties of interpretation. What one really needs is motion-picture recording, with the individual frames well spaced so that the motions are effectively speeded up by a factor, say, of 500 times in projection. The enormous success of Dr. R. R. McMath at the McMath-Hulbert Observatory, of the University of Michigan, in the use of motion-picture technique for spectroheliograms of the solar disk and prominences, shows the power of this mode of recording results. The graphic portrayal of the circulatory and eruptive features of the sun's atmosphere focuses immediate attention upon the truly significant features of the problem. And what Dr. McMath has achieved for the spectroheliograph could be even more easily adapted to direct photography of all kinds. Records of this character should assist astronomers to answer many of the questions raised in the foregoing discussion.

The recent development of new types of filters, made of quartz plates and polaroid sheets, greatly increases the possibilities for direct photography. This device is essentially a monochromatic filter and, if fully developed, would yield results comparable to those now obtained with the spectroheliograph. Evans, at Chabot Observatory, has obtained significant preliminary results with such filters. A combination of one of these filters with interferometers would give on a single photograph a three-dimensional picture of the motions, not only of the apparent drift but also of the speed toward or away from the observer.

The Surface is Granulated

The problems of sun-spots represent only a few of those in solar physics. The relatively clear areas between the spots are not without interest. Under high magnification, the sun's surface is seen to be flecked with myriads of tiny granules, only a few hundred miles in diameter. This granulation is subject to rapid fluctuations, indicative of the turbulent condition of the solar atmosphere. The appearance is not unlike that presented in an airplane view of a stormy sea on which the white-capped waves are dancing up and down. The entire picture may change in the course of a very few minutes. Indeed, very little else is known of the phenomenon, but cinematograph records appropriately taken with films of high contrast should disclose the character of the granulations and reveal the relationship that exists between them and the much larger spots. Observations over a sun-spot cycle, to find out the change of granulation with solar activity, would be particularly interesting.

Near the solar limb are often observed bright streaks or patches known as faculae. Although they are most commonly associated with sun-spots, faculae frequently appear in regions where no definite spots are visible. They may change their form in a space of several hours, yet some regions showing pronounced facular patches may persist for months. Thus, regarded as a form of

solar activity, faculae are much longer lived than spots. That the two phenomena are closely related, however, is shown by the fact that the disappearance of a spot is customarily followed by the appearance of faculae.

The Mysterious "Mountains" of the Sun

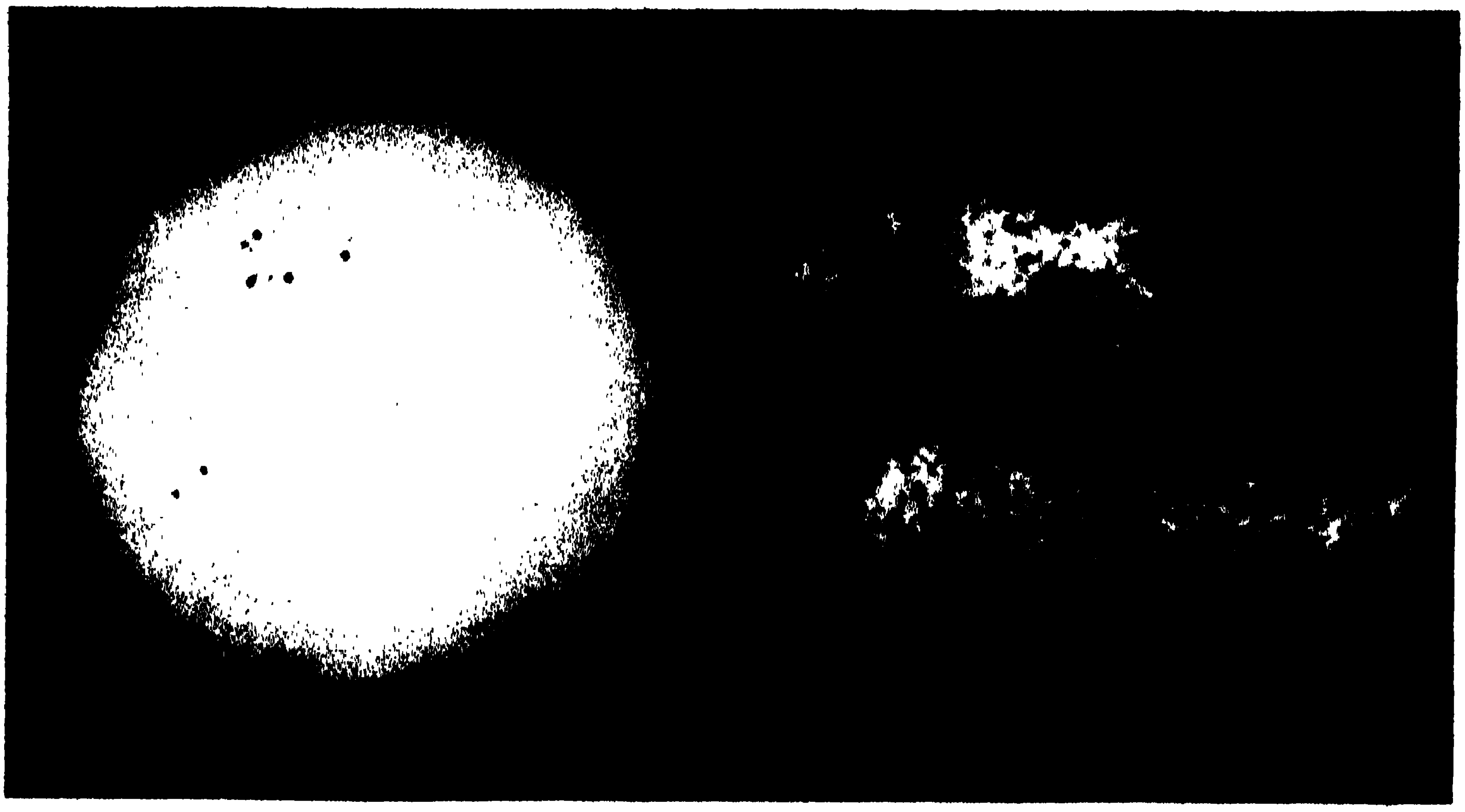
No satisfactory explanation of faculae has ever been given. Some observers have regarded them as a sort of cloud phenomenon, perhaps even a condensation, but this is unlikely. Their increased visibility at the limb, where the observer looks through a greater thickness of atmosphere, indicates that they are higher than the general level of the photosphere, or normal radiating surface. Clearly, more data are needed for their interpretation, but the indications are that they are a bulge in the sun's surface, in effect a "solar mountain." The phenomenon may be more technically described as a region where the atmospheric density is greater than that of the surrounding regions. What force can cause these semi-permanent elevations of the surface is not immediately obvious. It is possible, however, that sub-surface vortex tubes, struggling to preserve their identity under the pressure of overlying gas, might produce the effect. Here again, cinematograph records should help us to unravel the relationship.

The Turbulence of the Upper Solar Atmosphere

For the analysis of disk phenomena other than spots, granulation and faculae, the spectroheliograph, especially in the form employed at the McMath-Hulbert Observatory, stands unequalled. The surface details revealed by observations taken in the monochromatic light of some spectral line refer in general to higher atmospheric levels than those taken by the ordinary photographic process. The motion-picture records thus far obtained show a turbulence of the solar gases that can be appreciated in no other fashion. An ordinary series of exposures, taken say at fifteen-minute intervals through the day, show changes

Smithsonian Institution.

LANGLEY'S DRAWINGS OF A SUN-SPOT GROUP (1873)



Mt. Wilson Observatory.

COMPARISON OF DIRECT PHOTOGRAPH AND SPECTROHELIOGRAM

IN THE LIGHT OF CALCIUM. NOTE THAT THE CALCIUM FLOCCULI TEND TO FOLLOW THE GENERAL PATTERN OF THE FACULAE RECORDED IN THE DIRECT PHOTOGRAPH.

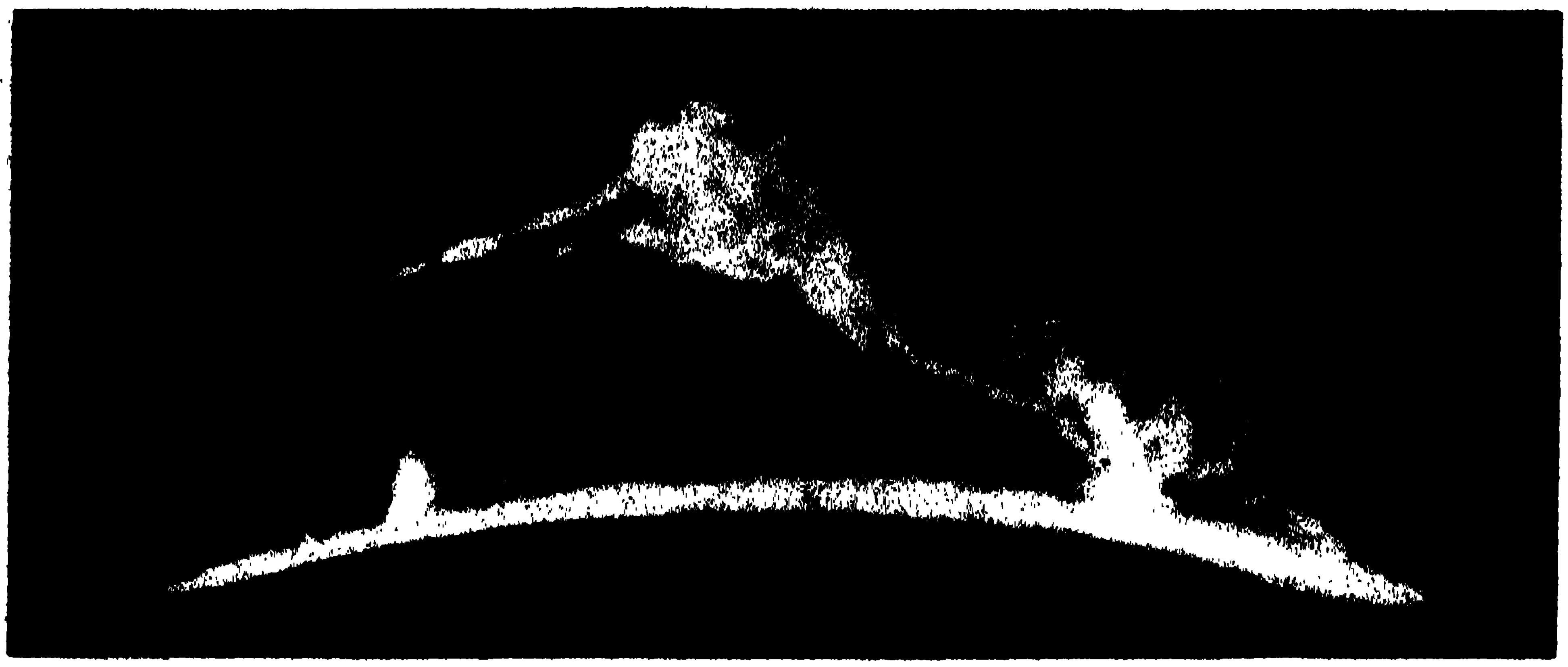
clearly, but the character of the transition stages is completely lost.

The clouds of hydrogen atoms, when the selected monochromatic line corresponds to light emitted by that element, are seen to be in rapid turbulent motion, like waves on a choppy sea. The observations plainly refer to that layer of atmosphere known as the chromosphere, which is best seen at the time of total solar eclipse. It thus appears as a ragged edge made up of spikes and filaments with a large prominence here and there projecting from behind the occulting lunar disk.

The prominences are also visible in projection against the solar disk as irregular absorbing patches sharply delineated against the brighter background. These are the dark "flocculi" of the solar surface. Bright flocculi, particularly prominent in spectroheliograms taken in light of ionized calcium, also exist. The sun-spots, too, appear, but their relatively more stately motions are lost in the general hurly-burly of the sun's upper atmosphere. There is some indication that the bright calcium flocculi respond to the vortex forces, with a slow rotation around the spot area. This reported phenomenon is worthy of more detailed investigation. The faculae and the granulations are completely invisible in ordinary spectroheliograms. The former will reappear if the wavelength region is shifted to a point outside the absorption line, but the resolution of the spectroheliograph is probably insufficient to reveal much of the granulation.

The Solar Spectrum

Of particular significance in any study of the solar surface is the physical interpretation of the spectra of various portions of the sun. Analysis of the intensities of the Fraunhöfer lines, studies of their displacements from normal positions as a result of convection currents in the atmosphere, the nature of line profiles over the disk, should continue to be profitable fields of investigation. Spectrographs of large dispersion and high resolving power, with interferome-



McMath-Hulbert Observatory.

AN INTERESTING PROMINENCE

NOTICE THE INTRICATE CHARACTER OF THE DETAIL. THE MOTION OF THE STREAMERS AT THE LEFT IS PREDOMINANTLY DOWNWARD.

ter accessories, should be employed. The studies will eventually culminate in increased knowledge of such important factors as the chemical composition, temperature, pressure and degree of atomic dissociation in the solar atmosphere. They will also give valuable physical data concerning the properties and behavior of atoms and molecules.

"Movies" of Prominences

The motions of prominences are best depicted by observations of the solar limb, with the solar image either occulted by an opaque disk or reduced in intensity by a dark circular filter. The spectroheliograph and the coronagraph stand about equal in their abilities to record these complex phenomena. The observations show that no two prominences are alike in behavior, although several distinct classes appear. Motion-picture technique has revealed what years of direct photography failed to disclose in detail: the intricacies of the prominence motions.

There is no such thing as an absolutely static prominence. All exhibit activity, some to greater degree than others. Those of the quiescent type display a variety of internal circulations, like the convection currents in a fleecy cumulus cloud. Others show evidence of a large-scale rotation, a sort of cyclonic effect, with the predominant motions parallel to the solar surface. Also, there are the common eruptive prominences, where great clouds of gas are blown violently away from the sun, apparently never to return. A fairly common variety consists of an inverted cone of gas, detached completely from the surface, except for "roots" running into the photosphere.

The peculiar and unexpected result of the new cinematograph studies is that the motion is predominantly downward. Since there is little if any evidence that material is being replenished in the main conical body, how the prominence maintains itself is a serious problem. This difficulty is even more graphically presented by still another variety of prominence, which might be described as a sort of reversed fountain. I say "reversed" because the matter is running backward from the top of the stream. Often numerous individual filaments exist, running downward in long graceful curves from a common point, each drawing upon an invisible source for its maintenance. In one remarkable record made at the McMath-Hulbert Observatory, the main body of the prominence springs suddenly into existence high above the

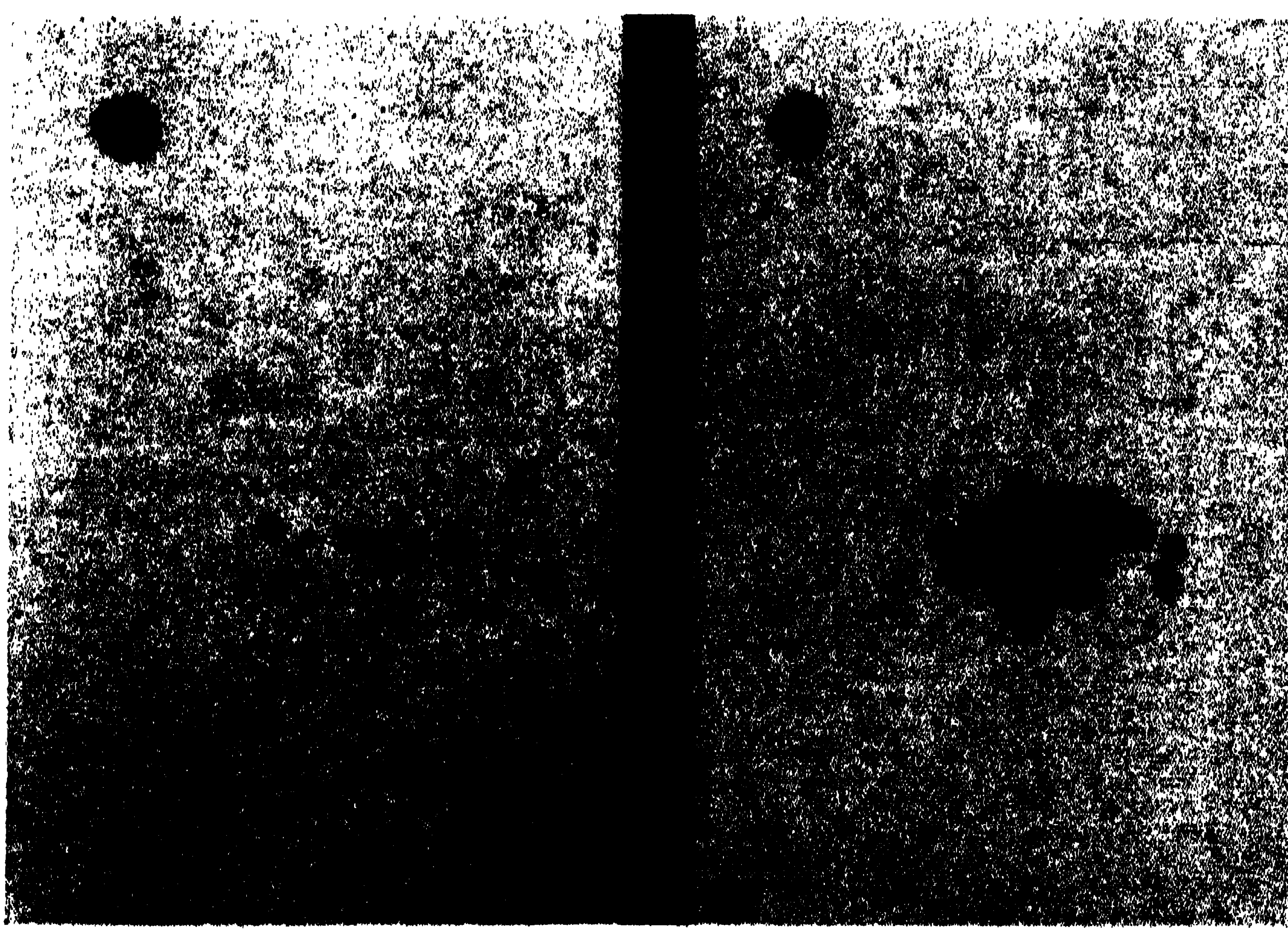
solar surface. The roots are formed as a subsequent development.

There seem to be three possible answers to the question of the origin of prominence material. The substances may be condensing from the corona where conditions render it non-luminous. They may rise invisibly from the photosphere. Or perhaps there are streams of material plying through the upper solar atmosphere, which becomes luminous only when they enter a region of high excitation, perhaps a restricted beam of ultraviolet radiation. The often expressed idea that the effect might be merely an excitation wave analogous to the terrestrial aurora is untenable; for that the motion is of real particles is proved by the magnitude of the observed Doppler displacements.

None of these theories, or at least none of them singly, is sufficient to account for all the observed effects. Further, one meets with serious difficulties in explaining why and how ionized gas should suddenly become luminous unless there is some action causing a rapid increase in its density in the neighborhood of the prominences. Intense force fields of electromagnetic origin might cause matter streaming in from all directions to converge into a certain volume. Charged particles, moving along magnetic lines of force produced by a sunspot, might behave in this fashion, and the afore-mentioned inverted cone is suggestive that the effect may occur. Observations of motions along coronal streamers would help to settle this important question.

Clouds That Weigh Thirty Million Tons

The chromosphere and prominences



Mt. Wilson Observatory.

TWENTY-FOUR HOUR DEVELOPMENT OF A SUN-SPOT GROUP

NOTICE THAT THE SPOT IN THE UPPER LEFT HAS REMAINED PRACTICALLY UNCHANGED WHILE THE GREAT GROUP HAS GROWN ENORMOUSLY. THE SMALL BLACK DOT AT THE BOTTOM REPRESENTS THE SIZE OF THE EARTH.

have many common features. In fact, one might say that a prominence is merely an overgrown chromospheric spike. In both phenomena the outstanding problems of interpretation are similar. How is the mass of a prominence supported for so long a time against the enormous pull of solar gravitation? The motion in the streamers seems to be one of almost uniform velocity, and shows none of the expected acceleration in its sun-ward fall. When accelerations do occur along the path, they arise almost instantaneously and the matter adjusts itself to a new uniform velocity.

The suggestion has been made—and the idea has met with wide acceptance—that pressure of sunlight is responsible for the effect. A quantitative calculation discloses, however, that if radiation pressure is the agent, we shall have to revise completely our conception of the temperature of the solar surface—so widely quoted at 6000°. For the mass of even a small prominence may be conservatively estimated at 1,000,000 tons. If solar gravity alone were acting, the prominences would fall from an initial height of 30,000 miles to the surface in an interval of only ten minutes.

The Lifting Power of Sunlight

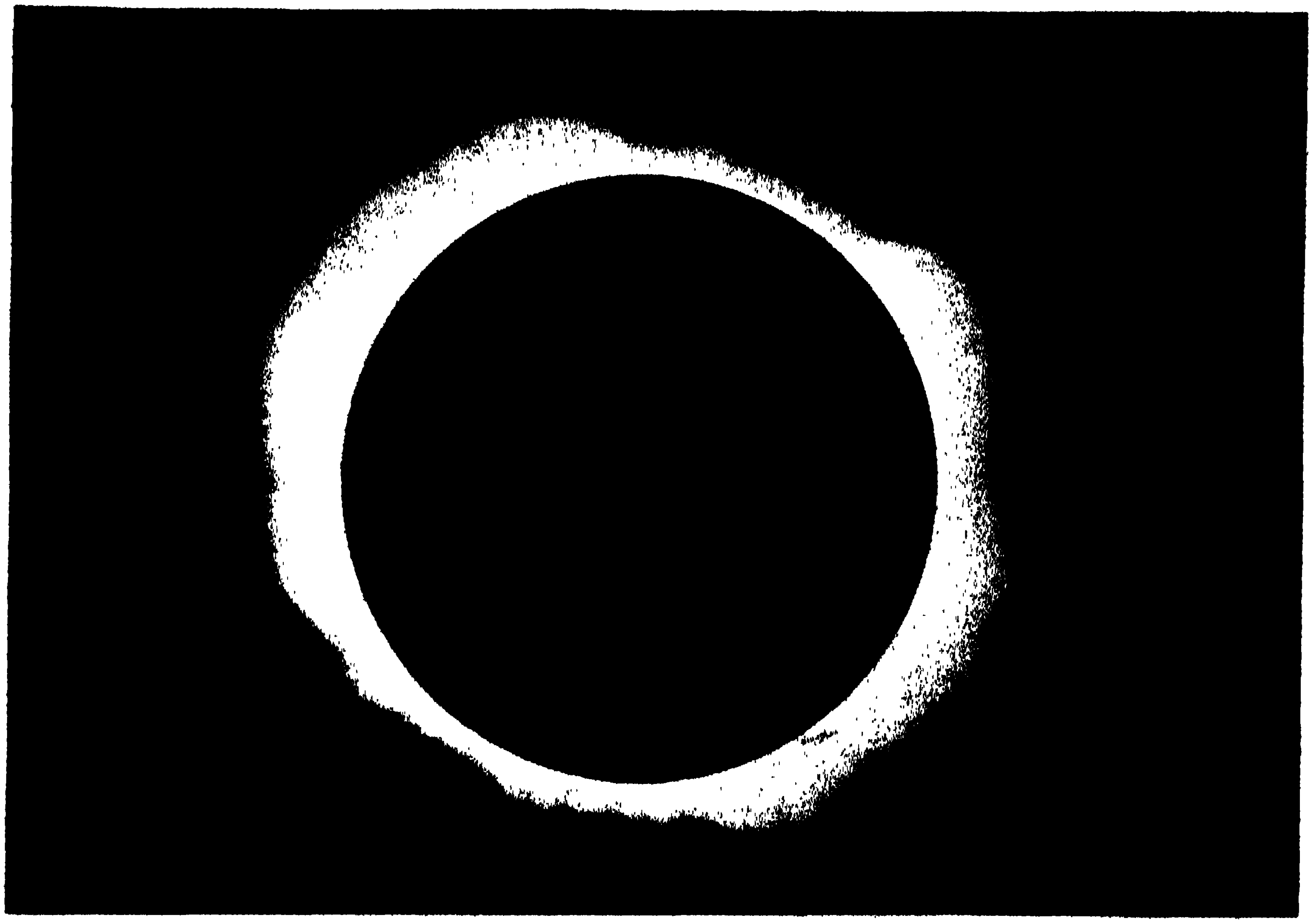
To prevent the collapse of this great tonnage, an enormous amount of radiation is required, far more than the sun could furnish if it were to radiate in all wave-lengths as if its temperature were 6000°. Furthermore, since the radiation must be absorbed if it is to have any effect in support, and since hydrogen, the most abundant constituent of prominences, can absorb radiation effectively only in the spectral regions short of 1,000 Ångstrom units or so, large quantities of energy must be escaping from the sun in the extreme ultra-violet. Our atmosphere, unfortunately for the astronomical observer, is completely opaque to light of this wave-length, so that no direct check can be obtained. But a simple calculation shows that the ultraviolet radiation temperature of the sun must be at least 12,000°, if radiation pressure is the source of support.

Fortunately, there is another observational fact that points toward exactly the same conclusion. The spectra of the chromosphere and prominences, obtained at total solar eclipses, show very intense spectral lines of hydrogen and helium. These elements require a very high degree of excitation before they will shine at all, and theory is conclusive in specifying that the amount of radiation we receive could be produced only by a source with a temperature from 12,000° to 25,000°. The higher figure comes from the calculation for helium.

As a matter of fact, there is a third confirming observational datum of a totally different character. The degree of ionization in the electron layer high in the earth's atmosphere, the layer that is responsible for the reflection of radio waves around the earth, also demands a high radiation temperature for the solar ultra-violet.

We seem forced to conclude, therefore, that abundant radiation is present, and we may provisionally accept the ultraviolet excess of the sun's radiation, although in doing so we are merely replacing one difficulty with another. For then we are led to ask: how can this energy escape from the sun? And why, in passing through the lower levels of the solar atmosphere, does it not produce observable effects in the ordinary absorption spectrum? To neither of these questions has a satisfactory answer been proposed, although the second is by no means as serious as the first. In fact, the latter query may possibly be countered with the statement that the observed intensities of a few absorption lines, like those of oxygen, hydrogen and helium, can be better explained if the excess ultra-violet energy is present.

Merely postulating the existence of radiation pressure, however, falls far short



Yerkes Observatory.

THE SOLAR CORONA

THIS PHOTOGRAPH, TAKEN MAY 28, 1900, IS ILLUSTRATIVE OF THE MINIMUM TYPE OF CORONA, WITH DISTINCT "BRUSHES" NEAR THE POLE AND LONG EXTENSIONS PARALLEL TO THE EQUATOR.

of solving the entire problem of prominence motion. There is the unsolved problem of how so delicate a balance is maintained automatically between radiation pressure and gravity. There is a chance that, if the ultra-violet radiation consists in part of intense emission rather than absorption lines, an equilibrium can be secured. An atom, moving too fast, would be unable to absorb the line, because of the Doppler effect. Its motion would, in consequence, be checked. I confess, however, that the idea borders on the speculative. The uniformity of velocities in most prominences indicates that no persistent accelerations are present, except perhaps those in a direction perpendicular to the motion, as the quasi-circular trajectories of the streaming material indicates. It seems unlikely indeed that either radiation pressure or gravitation can be called on to explain the curved trajectories.

Magnetic Fields May Assist

The curvature suggests that magnetic fields may play a part in the phenomenon. There are two partial explanations available. It is well known that the motion of electrified particles in a magnetic field is perpendicular to the magnetic lines of force. Are the great curved trajectories, then, produced by the circling of electrons around a magnetic field more or less parallel to the solar surface? The radius of the trajectory is inversely proportional to the field intensity. The fields thus calculated are so very minute that one would scarcely expect them to set up the electric currents that must necessarily accompany such action.

If the motion of the matter is toward the right, let us say, the electrons would have to flow to the left. And since the material must be neutral as a whole, the matter can not move until a complete

electric circuit is established. A prominence so constituted would consist of matter streaming upward from the photosphere, reaching a maximum and finally descending. The resultant motion is so unprominence-like that we may discard the idea.

The second possibility is more promising. Suppose that an intense magnetic field, *e.g.*, that of a sun-spot, is in the neighborhood. The lines of force, curving from the spot toward the prominence, will be very nearly parallel to the solar surface in this region. In the intense magnetic field electrons will whirl in very tiny orbits, a few millimeters in diameter. The ions will traverse somewhat larger orbits in the opposite direction, but there will be no charge separation, because the orbits are so small. The magnetic field exerts a sort of stabilizing action and neither gravitation nor radiation pressure can act in normal fashion. There results a sort of gyroscopic action. A sudden blast of radiation would cause the atom to move, not upwards, but in a direction perpendicular to the magnetic lines of force, *i.e.*, essentially parallel to the solar surface.

Mt. Wilson Observatory.

BIPOLAR SPOT GROUP

THE DARK HYDROGEN MARKINGS SHOWN ON THE SPECTROHELIOGRAM EXHIBIT A PATTERN RESEMBLING THAT OBTAINABLE IN THE LABORATORY FROM IRON FILINGS SPRINKLED ON A PAPER SUPERIMPOSED ON THE POLES OF A HORSE SHOE MAGNET. THERE IS A POSSIBILITY THAT THE INTENSE MAGNETIC FIELD OF THE SUN-SPOTS MAY PRODUCE THE EFFECT. EVEN THOUGH THE HYDROGEN THAT EMITTED THE LIGHT HERE RECORDED IS NEUTRAL, A FAIRLY LARGE PROPORTION OF THE ATOMS ARE IONIZED AND THEREFORE SUBJECT TO THE FORCES OF THE MAGNETIC FIELD. NOTE THE BRIGHT HYDROGEN FLOCCULI BETWEEN THE PAIR OF SPOTS. THIS ZONE IS PROBABLY AN AREA OF INTENSE PROMINENCE ACTIVITY.

Although interatomic collisions tend to complicate the problem, the predicted effect is enough like that observed in prominences to warrant further investigation. In fact, the observations indicate that prominences, at least some of which have definite vortical character, may also possess magnetic fields. And the very common appearance of double prominences, connected with an overlying arch, may well be analogous to a bipolar spot. The tendency of such objects to "erupt" eventually may possibly arise from a dying of the associated magnetic fields. The so-called sunspot type of prominence, consisting of semi-periodic ejections and withdrawals of flame-like tongues, is further evidence in favor of this picture. Also should be mentioned the peculiar striations exhibited by the bright and dark flocculi in the neighborhood of spots—structure similar to that of iron filings in the vicinity of a magnet. Of course the hydrogen photographs are taken in the light of a neutral atom, but one should recall that the gas is ionized a large part of the time and hence subject to the forces here described.

It should be emphasized that the magnetic fields merely influence the motion. They provide no acceleration in the direction the particle is moving. Atoms are free to slide up or down, *parallel* to the lines of magnetic force, and react

naturally to the component of any other force that is exerted in this direction. Near a spot, where the lines are nearly vertical, the field exerts little or no supporting action. The sun's general magnetic field may also play a part.

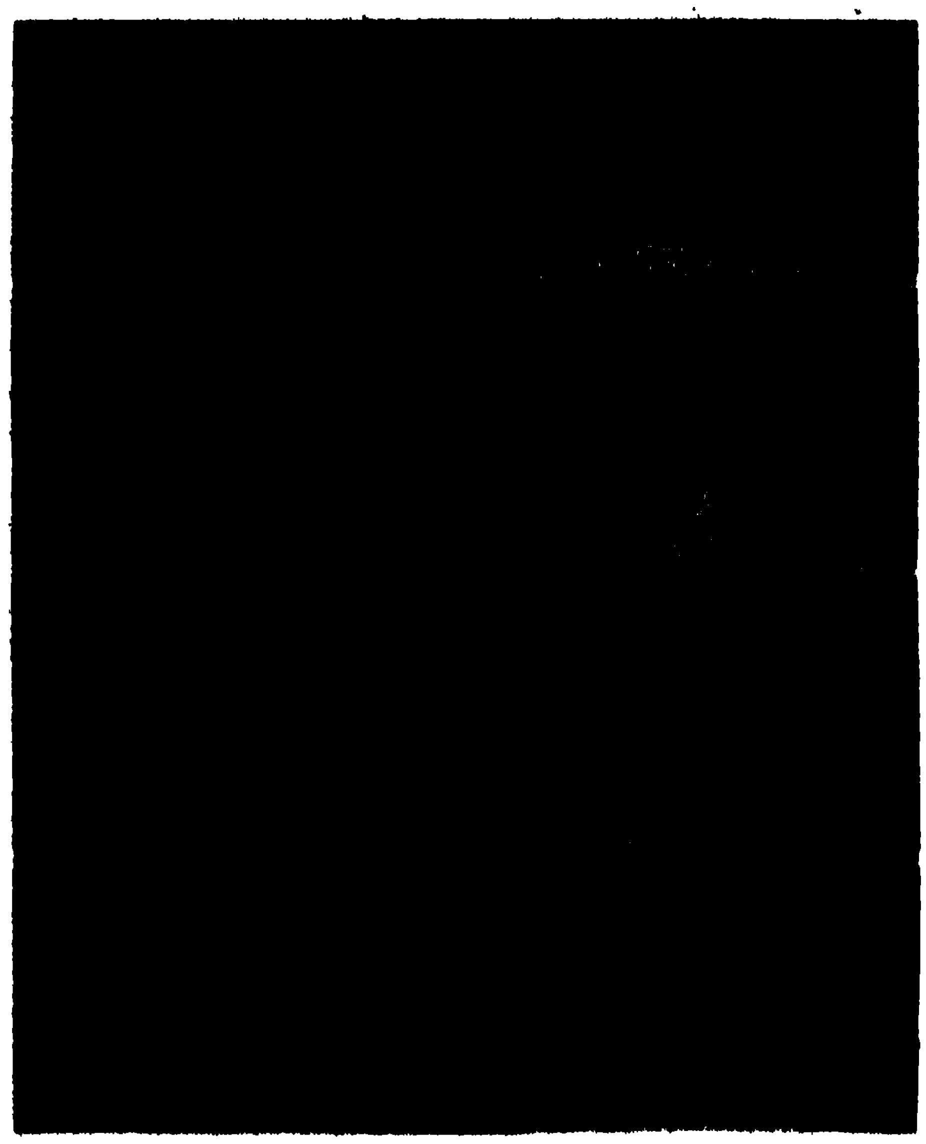
Whether electric fields exist or not is still an open question. The charge of the earth is far greater than one would expect to find on the basis of simple equilibrium theory. One can not now definitely rule out the existence of similar fields on the sun. They may be large enough to exert an appreciable effect on the motions of prominences, though they probably do not contribute appreciably to the support of the atmosphere.

This tentative theory suggests a multiplicity of observational problems: study of the curvature of prominence streamers, their relation to one another and to neighboring spots, measurements of the patterns exhibited by flocculi near spots, and perhaps even the detection of the Zeeman splitting of prominence lines in the magnetic fields. There is room, also, for allied theoretical studies, such as prominence vortices, the nature and origin of the magnetic fields, etc.

Problems of the Solar Corona

One must not forget that the prominence motions occur in a medium that is far from being a perfect vacuum, *viz.*, the solar corona. All too little is known of this interesting portion of the solar atmosphere. The emission lines have not been identified with those of any known element, although they are undoubtedly due, not to a new substance, but to a familiar one in some special condition of excitation.

The corona consists of a very extensive envelope of gas, in which streamers and condensations in the form of ribbon-like filaments exist. The form is roughly symmetrical about the axis of rotation, with the greatest extensions occurring usually over the spot zones. In the corona, as in prominences, the characteristic pattern is again suggestive of the influence of a magnetic field.



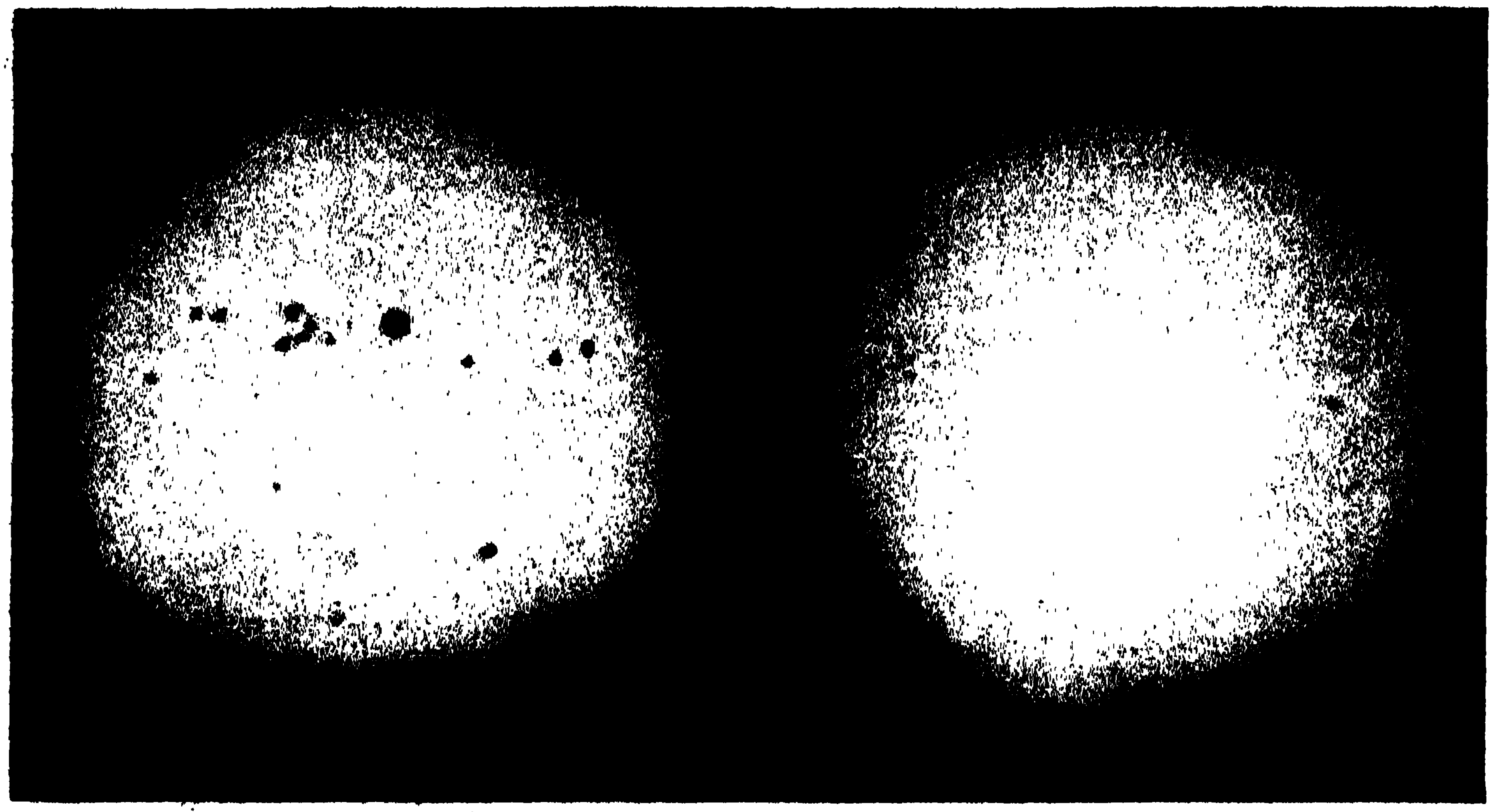
McMath-Hulbert Observatory.

LIFE AND DEATH OF A PROMINENCE

THIS SELECTION OF VIEWS FROM A COMPLETE MOTION-PICTURE RECORD SHOWS THE TREMENDOUS DISTURBANCE RISING FROM THE LOWER CHROMOSPHERE, THROWING OUT A BRILLIANT LOOP WHICH LATER DIES AWAY. MEANWHILE, THE SUSPENDED CLOUD PROMINENCE, WHICH PROBABLY LIES WELL IN FRONT OF THE RECORDED DISTURBANCE, SHOWS ONLY MINOR CHANGES.

Essentially nothing is known of internal coronal motions. It probably rotates as a whole, along with the sun; radial expansion probably exists. The strong curvature of the filaments in the neighborhood of sun-spots suggests that rapid changes may occur. But the difficulty of observation has made it impossible for us to determine much else except its general variation with the sunspot period.

The development of the coronagraph and coronaviser have opened new fields for observation and interpretation. Lyot's pioneer work, in France, proved so successful that two similar instruments have been built, one by Waldmeier, in Switzerland, and one by Harvard Ob-



Mt. Wilson Observatory.

THE SUN AT TIMES OF MAXIMUM (LEFT) AND MINIMUM SPOTTEDNESS

servatory, now stationed at Climax, Colorado, at an altitude of 11,500 feet. With these instruments, fairly regular observations should be possible of at least the inner corona. Cinematograph records should disclose the nature of internal motions and their relation to those of the prominences.

It is now known that there exist prominences of purely coronal nature, rich in light of the unidentified lines, but lacking the customary chromospheric radiations. These prominences are known to be associated with regions of high excitation in the chromosphere, and further investigation of the problem should be possible with the coronagraph. Spectrographic observations to search for new lines and provide better wave-lengths of the old ones, will assist in the identification of the atoms responsible for the mysterious radiations. As previously mentioned, the coronagraph is a powerful instrument for the study of prominence motions.

The lower corona, the prominences and even the chromosphere are intermingled. The coronal lines attain their greatest intensity within the boundaries of the chromosphere. Hence, as mentioned above, the resistance of the corona to prominence motions, the effects of viscosity, must be studied. The possibility exists that prominence motions can not be considered separately at all, and that one must treat the flow of gases in the sun's extensive atmosphere as a problem in gaseous hydrodynamics.

The Quantity of Solar Radiation

There is one final and extremely important aspect of solar observation: the question of the quality and quantity of the sun's radiation. Here, indeed, is presented one of the most complicated of all the observational problems. The difficulties are imposed, not by the sun itself, but by the extreme accuracy required and by the earth's atmosphere, through which we must make our measurements. We must correct for the absorption caused by the various constituents of the atmosphere. The technique is far from simple, and great credit must go to C. G. Abbot, of the Smithsonian Institution, for his long and careful investigation of the problem.

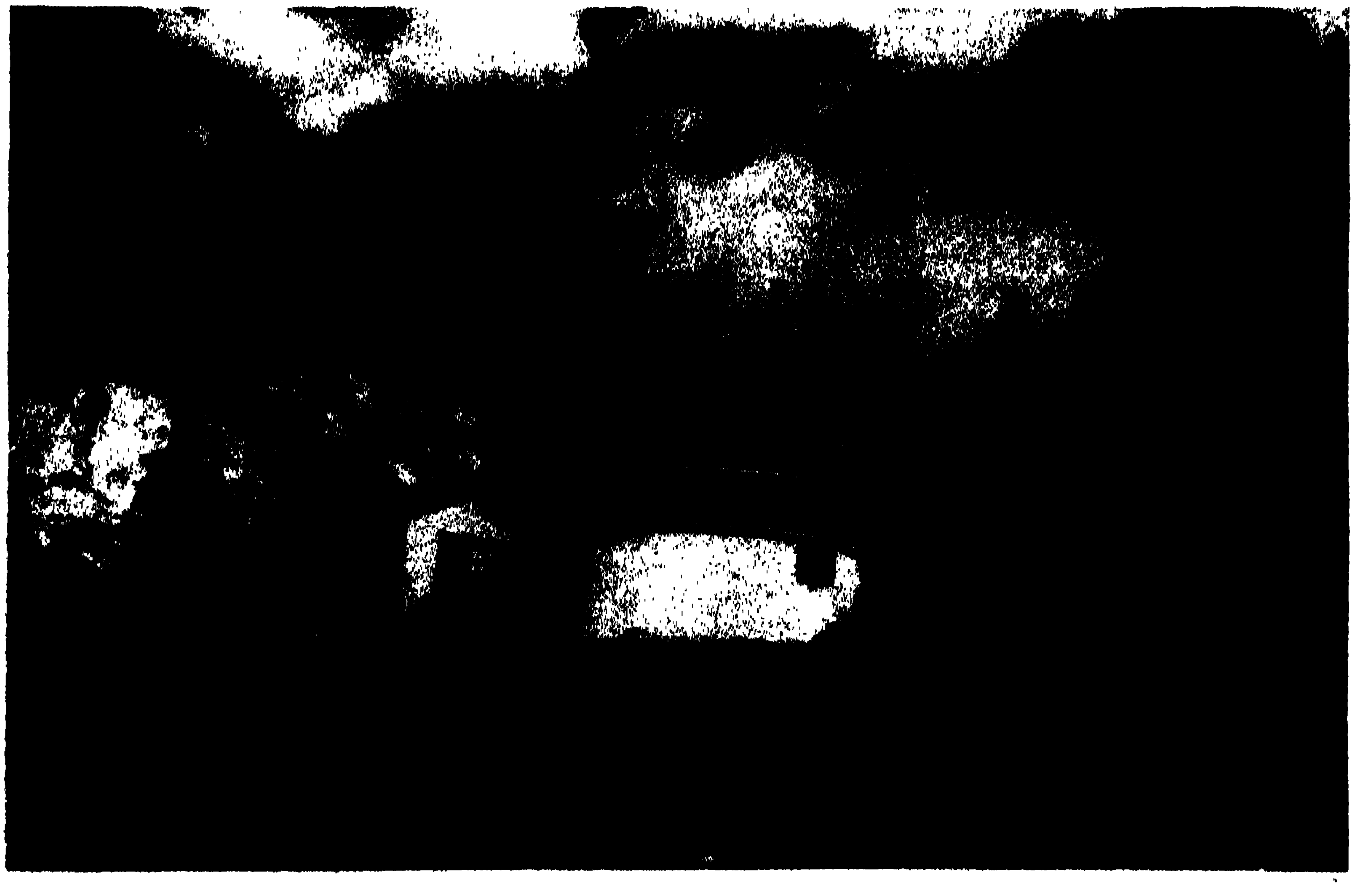
His results may be briefly summarized.

In the spectral region accessible to observation, the sun's energy curve corresponds closely to that of a black radiator at temperature of about 6,000° Absolute. There is some discrepancy in the ultra-violet, where the solar radiation is somewhat less than expected, perhaps because of the large number of intense overlapping absorption lines. The total radiation is estimated by interpolation and extrapolation over the absorption bands produced by molecules of the earth's atmosphere. The value of this total energy is known as the solar constant.

In the strictest sense, the figure is not constant. Abbot has shown that the amount fluctuates by about one per cent. Some periodicities are indicated, the best substantiated being cycles of approximately eleven years and of eleven months, respectively. The former, clearly, is associated with the sun-spot variation. Larger fluctuations in the magnitude of the ultra-violet energy have been suspected but not confirmed because of the difficulty in elimination of the absorption of the earth's atmosphere.

The earth's atmosphere! A perpetual nightmare to astronomical observation! From the standpoint of terrestrial life, it is perhaps provident that atmospheric ozone absorbs the far ultra-violet. None whatever of radiation short of about 2,800 Ångstroms penetrates the ozone shell. We might as well be living in a dark cellar, for all the solar radiation that comes through in this spectral range.

And yet this radiation is highly important from the terrestrial point of view. As I previously stated, it is chiefly responsible for the electrification of the atmospheric layer that reflects radio waves. Our estimates of the quantity of this far-ultra-violet energy must



FREMONT PASS STATION, HARVARD OBSERVATORY, CLIMAX, COLORADO

THIS BUILDING HOUSES THE NEW CORONAGRAPH, WHICH HAS JUST BEEN INSTALLED. THE UNUSUAL SHAPE OF THE "DOME" WAS CHOSEN BECAUSE OF THE HEAVY SNOWFALL, WHICH AVERAGES ABOUT TWENTY FEET PER YEAR AT THE ALTITUDE OF 11,500 FEET.

be largely inferential. Abbot assumes that the solar curve follows that of a black radiator at 6,000°, with a depletion of about 70 per cent., and thus deduces a correction of about 4 per cent. to be added to the measured energy.

On such an assumption the energy lying in the extreme ultra-violet, at 1,000 Ångstrom units and beyond, is negligible —about one millionth of the whole. Nevertheless, if the sun radiates in this spectral region as if its temperature were 12,000° or higher, as the excitation of the hydrogen chromosphere and ionosphere seem to demand, an additional factor is required, which may amount to several per cent. Further, radiation in this particular region may fluctuate enormously with solar activity. Apparently the only way open for investigating it at present is from observations of the spectrum, or possibly also from study of the solar corona.

Investigation of the solar constant should be continued, both by the methods developed at the Smithsonian Institution and by any new experimental procedures that can be devised to determine the troublesome atmospheric corrections. Brian O'Brien and his colleagues at the University of Rochester make use of airplanes and balloons to eliminate the lower atmospheric levels. Such studies are profoundly important.

The Sun and the Earth

There is scarcely one of all the foregoing phases of solar research mentioned in the foregoing discussion that does not have some bearing on the interesting problem of solar-terrestrial relationships. For all contribute to our knowledge of the sun and how it operates. The results of the investigations outlined point directly to a determination of the quantity and quality of solar radiation and of the various corpuscular emissions, ions and electrons, some of which may reach the earth.

The picture will be complete only if the physicist, the radio-engineer, the geophysicist and the meteorologist are brought into close collaboration. There are the ionosphere problems, so closely allied with magnetic storms and aurorae. And, finally, there is the ever-significant question of the relationship between solar variability and weather phenomena. The foregoing researches should give new indices, perhaps far more sensitive than sun-spots, for estimating the state of solar activity. And, what is even more important, they may provide a basis for a definite physical tie-up between the sun and variable weather phenomena. Such a conclusion would be of great assistance in guiding the statistician who seeks to correlate "weather" on the sun with that on the earth.

THE ELECTRON MICROSCOPE

By THEODORE A. SMITH
ENGINEERING PRODUCTS DIVISION, RCA MANUFACTURING COMPANY

ALTHOUGH announcement of the development of electron microscopes to a point where they might be applied to scientific research problems is still relatively new, already instruments are being manufactured for the leading scientific laboratories in the United States. In addition, those who have had the opportunity to use electron microscopes have reported a number of interesting discoveries which are indications of what may be expected in the future when further research work has been done.

Before the advent of the electron microscope, information regarding objects too small to be seen could be obtained only indirectly, by estimating sizes, by the use of spectroscopic means or the ultra centrifuge. Naturally, data on the size, shape or distribution of colloidal particles, the structure of plastics and similar information would be valuable to industry. There is every reason to believe that many virus bodies, too small to be seen with optical microscopes, may be responsible for diseases. The electron microscope opens up fields of research in the world of the very small which may be of inestimable value to humanity.

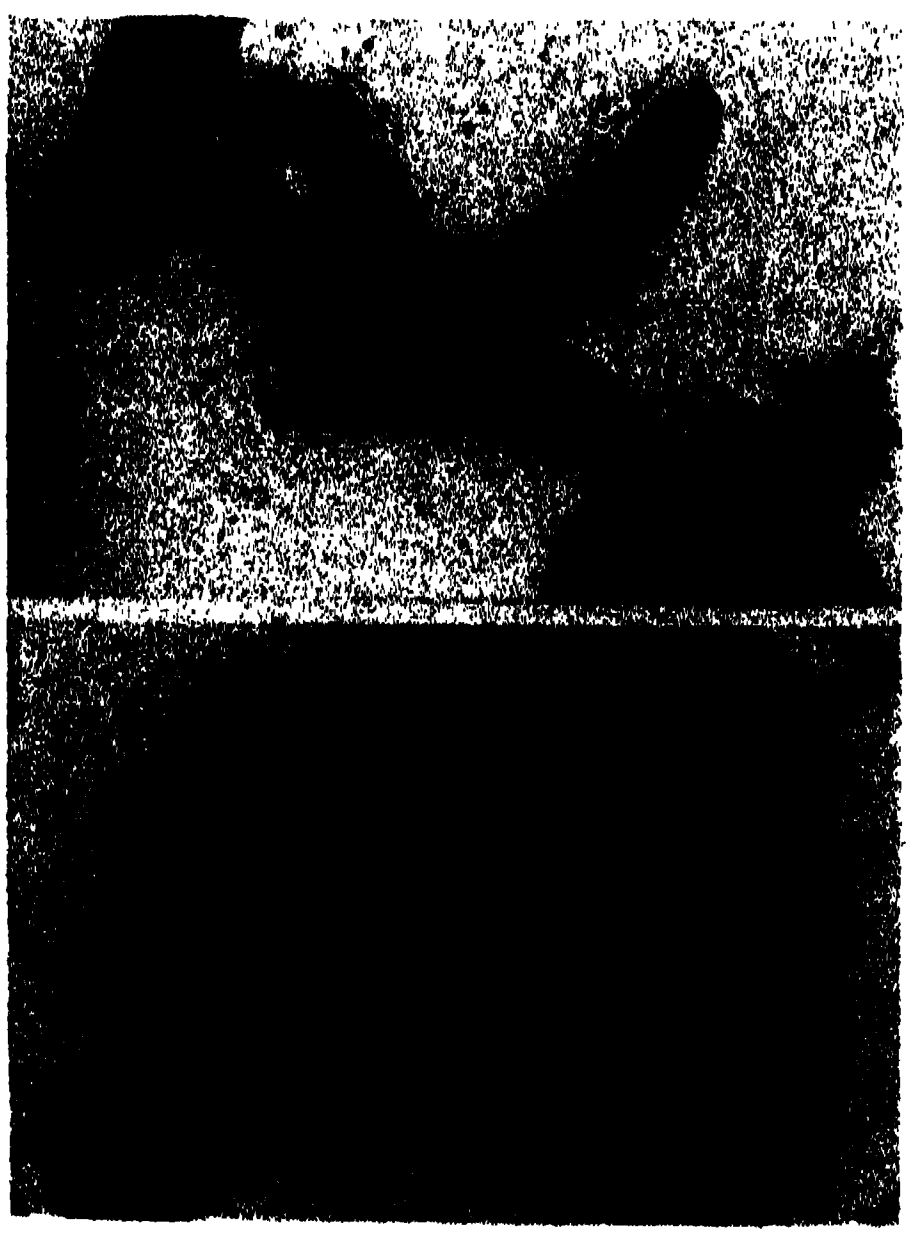
Why can not such small particles be seen with optical microscopes? Reasons why this is the case will make clear the need for a new type of microscope.

Ordinarily, two points separated by a

STREPTOCOCCUS BETA HAEMOLYTICUS MAGNIFIED 24,000 DIAMETERS

THE ORIGINAL MICROGRAPH SECURED WITH THE POWERFUL ELECTRON MICROSCOPE GAVE A MAGNIFICATION OF 45,000 DIAMETERS. AT THIS MAGNIFICATION A HUMAN HAIR WOULD HAVE A DIAMETER OF MORE THAN 10 FEET.

distance less than 0.2 millimeters are not visible as discrete points but will be seen only as a single blur. By the use of a simple magnifying glass, it is possible to extend the range of observation downward about ten times so that it is possible to distinguish points separated by about .02 millimeters. A simple magnifying glass may even be carried further, and it is interesting to note that Leeuwenhoek (who is usually credited with the invention of the microscope) used a simple magnifying glass for his observations and was able to distinguish many animalcules, although he apparently had exceptional eyesight. The use of the compound microscope extends the range of visibility to objects 1,000 times smaller than could be seen with the unaided eye. This means that with the ordinary instrument, points separated by .0002 millimeters may be observed.



TUBERCULOSIS BACILLI
Above: HUMAN BACILLUS MAGNIFIED 22,000 DIAMETERS, SHOWING HITHERTO QUITE UNKNOWN DETAILS. THE ORIGINAL MAGNIFICATION WITH THE RCA ELECTRON MICROSCOPE WAS 42,000. *Below:* BOVINE BACILLUS MAGNIFIED 44,000 DIAMETERS. REDUCED FROM A MICROGRAPH HAVING A MAGNIFICATION OF 84,000 DIAMETERS.

In the extension of the range of vision up to magnifications of 1,000, the principal limitations are those caused by optical deficiencies in the lenses which may be minimized by special lens formulas. However, above magnifications of 1,000 a new limitation creeps in; namely, the wave-length of the medium used to view the specimens, that is to say, light, itself.

The wave-length of light in the visible range is in the order of .0004 to .0008 millimeters, and it will be apparent that many of the bacteria or other objects which scientists wish to examine are smaller than this value. Mr. Hillier, of Dr. Zworykin's electron research group who have been responsible for the development of this instrument, offers an interesting parallel which helps to make this point clear. If we drop a stone into a small pond causing ripples to radiate from it in all directions and if these ripples chance to strike a vertical stake in the pond, a disturbance will be caused in the regularity of the ripples as they pass the stake. However, as the wavelets pass beyond the stake, the disturbances are smoothed out, so that several feet away the wavelets are nearly parallel and it is difficult to tell that the stake had interrupted their passage at all.

Now, things are seen due to their disturbing effect on light waves. If no disturbance is produced, we can not see them. Therefore, if objects are much smaller than the wave-length of the medium used to observe them, whether it be water or light, they produce a disturbance which is very small and, hence, can not be easily detected. If, instead of a small stake in the pond, we had observed the effects of a boat shadowing the waves radiated by the dropping of a stone, we would discover that beyond the boat the waves were entirely obscured or, in other words, the effect of the boat was to disturb the waves to a considerable degree.

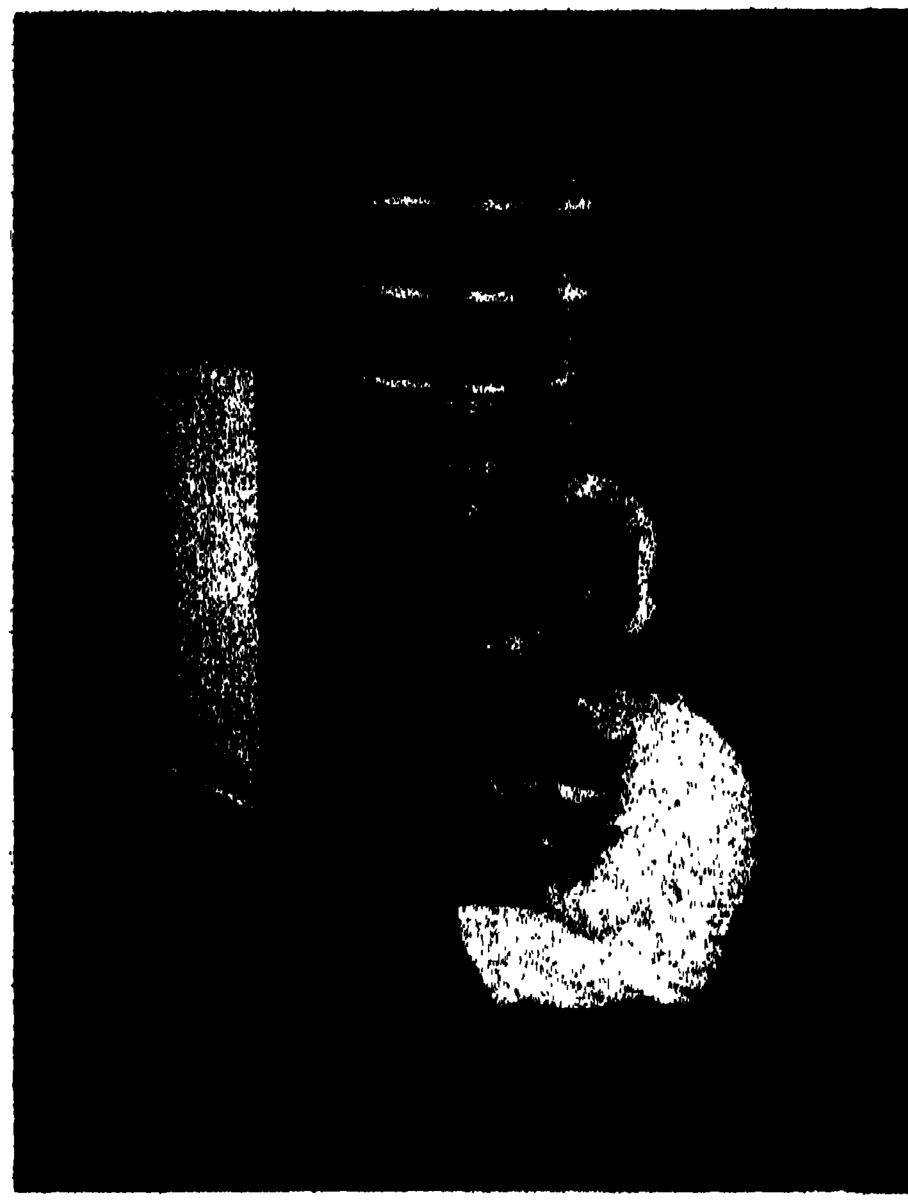
Thus, objects much larger than the observing medium will produce an effect which may easily be detected and this, of course, is what permits us to see everyday objects.

One solution, of course, is to employ light of shorter wave-lengths, and this has been carried forward in the ultra-violet type of microscope so that a magnification of approximately 2,500 is possible; this permits us to observe particles separated by a distance of slightly less than .0001 millimeters.

Other means also exist for stretching the range of the optical type microscope, but they can not be extended indefinitely so that it appears that the scope of seeing smaller and smaller objects by means of light is definitely limited to a useful magnification of approximately 2,500 diameters. If we go above this point and magnify to a greater extent, we do not discover any new detail but merely make the resulting image larger. As long as the image can be made as big as .2 millimeters, we do not gain any new information by further enlargement.

The electron microscope represents a means to extend the scope of seeing to smaller objects. It makes use of a stream of electrons with which is associated a wave-length many times smaller than even that of ultra-violet light. In fact, the wave-length of an electron beam, having a velocity of 60 kilovolts, such as is used in the commercial type electron microscope, is small enough so that theoretically it should be possible to see atoms.

Other effects, however, prevent this enormous resolution from being realized, but, practically, it is possible to observe large molecules; and magnifications up to approximately 100,000 may be employed before exhausting the detail permitted by this medium. In other words, instead of a limitation of observing particles separated by a distance of .0001 millimeters, we can now observe particles separated by a distance of .000002 millimeters so that we have extended the range of seeing to things 1/50 of the minimum size observable with the best light microscope.



THE NEW ELECTRON MICROSCOPE
BEING USED BY DR. V. K. ZWORYKIN, STANDING, DIRECTOR OF ELECTRON RESEARCH OF THE RCA LABORATORIES, AND JAMES HILLIER, SEATED, CO-DEVELOPER OF THE NEW ELECTRON MICROSCOPE.

Obviously, with a stream of electrons it is impossible to employ the ordinary type of lenses which are used in the more familiar microscope since electrons do not pass through very thick or dense materials. However, a magnetic field produced by a coil with a current flowing through it will deflect a stream of electrons and by properly designing the coil, it may be made to act as a converging lens does and, hence, to produce an image of the disturbance caused when electrons pass through the material to be examined. In the RCA electron microscope three such lens structures are employed. The first serves as a magnetic condenser lens, having a function similar to that of the sub-stage condenser in an ordinary microscope; the second lens produces a magnification of approximately 100 times and acts as a magnetic objective lens. The third mag-

ELECTRON MICROGRAPH SHOWING APPEARANCE OF ZINC OXIDE PIGMENT
MAGNIFICATION ABOUT 24,000 DIAMETERS; ORIGINAL MAGNIFICATION, 44,000 DIAMETERS.

A FAMILIAR BACTERIUM—AERO BACTERIUM CLOACAE
MAGNIFICATION ABOUT 30,000 DIAMETERS; ORIGINAL MAGNIFICATION, 54,000 DIAMETERS.

netic lens acts as an image projector and provides additional magnification which may be required to bring the detail to a size which may be readily observed. The electron stream is generated by a heated filament similar to that in a radio tube and since molecules of air would interfere with the normal passage of electrons, vacuum pumps exhaust the chamber to a pressure corresponding to about 10^{-5} millimeters of mercury.

When the electron stream passes through the object to be examined, the denser portion of the material will cause the electrons to be scattered in various directions. The more dense the substance, the more scattering will take place and, hence, fewer electrons from this portion of the specimen can get through the aperture in the objective and reach the viewing screen. In addition, if the atoms of a particular material are heavy they will also serve to deflect more electrons than if they were light. Thus, the image formed by the electron stream is built up due to the atomic weight and the density of the substance being examined.

Electrons are entirely invisible, but if the stream is permitted to strike a fluorescent screen an image will be created of light and dark portions corresponding to the electron density. Hence, in the electron microscope the image is seen not by direct observation but by looking at the pattern produced on the fluorescent screen. Electrons will also affect a photographic plate in the same manner as light and, if the fluorescent screen is removed and a photographic plate substituted, it is possible to obtain a permanent record. Such pictures can not be called photographs since they are not produced by light but have been termed micrographs.

Although it is necessary to introduce the specimens into a vacuum while observations are being made, air locks are provided which allow air to enter only a small chamber which may be pumped out separately so that the vacuum of the entire instrument is not spoiled. It is possible to move the specimen about in order to examine various portions of the field and, in fact, the procedure of taking a micrograph with the electron microscope is actually simpler in some respects than the equivalent procedure when using an optical instrument. For example, in several instances it has been possible to obtain negatives of the material under observation which had been brought into the laboratory in a test-tube only ten minutes before.

Since a high voltage is required to accelerate the electrons and to cause them to travel in straight lines, it is important that this voltage be constant or the resulting picture will be blurred. Dr. A. W. Vance has designed an extremely stable power supply system which greatly reduces these fluctuations and permits long-time exposures without blurring.

The entire unit is contained in a structure comprising a metal rack containing the power supply equipment and a column in front of the rack which is the microscope tube, itself. The electron microscope is focused by varying the current through the magnetic lenses and this control, as well as the magnification controls, is mounted on the front panel of the power supply rack. With the exception of a vacuum fore pump, the microscope is self-contained and operates from a 110 volt, AC supply requiring only about 2.5 kw power.

As an indication of the simplicity of its use, it has been possible to bring persons who are acquainted with laboratory procedure, but who had never used the electron microscope before, to the instrument and to have them taking pictures with it two or three hours after they first see it.

Because of this simplicity in operation, it is expected that research and development work will be facilitated and it is hoped that much of importance may be disclosed which now lies beyond the range of visibility.

HOW DARWINISM CAME TO THE UNITED STATES

By Professor W. M. SMALLWOOD

HEAD OF THE DEPARTMENT OF COMPARATIVE ANATOMY, SYRACUSE UNIVERSITY

It is interesting to drop back to the first meeting of Charles Darwin and Asa Gray, which took place in London. This event, simply recorded by Asa Gray in his journal on January 22, 1838, gives no intimation of the important series of happenings which were to follow two decades later: "We there met Mr. Darwin, the naturalist who accompanied Captain King in the *Beagle*."[1] Professor Gray made his first voyage to Europe while on a leave of absence from the newly established University of Michigan.

Thirteen years later, early in 1851, when Professor and Mrs. Gray made a journey to Europe, Mrs. Gray wrote in her diary the following account of the second meeting of those two great men:

> And one day came an invitation to lunch from the Hookers', 'to meet Mr. Darwin, who is coming to meet Mr. Hooker; is distinguished as a naturalist.' Mr. Darwin was a lively, agreeable person.[2]

Owing to the strange ways of mice and men, there seems to be no way of learning what influenced Gray to begin writing to Darwin, and Darwin to continue the correspondence. We read that Gray's letters to Darwin previous to 1862 were mostly destroyed, and those of a later date more or less injured by mice.[3] It is impossible to do more than outline the influences that led Darwin to take Gray into his confidence after two casual meetings. This was an honor which had been extended to but two Englishmen—Joseph D. Hooker and Sir Charles Lyell.

Gray had written some of his philosophic conclusions about "species" to Hooker in 1854, noting that "scientific Systematic Botany" rests upon species "created with almost infinitely various degrees of resemblance among each other." This unpublished letter[4] indicates that there is variation in some species; and, because of its importance in almost anticipating Darwin, is quoted rather fully:

> But who shall lay down a rule as to *how much* two plants shall differ in order to be admitted as specifically different? That must be determined by observation and experience alone:—which show that while some species are *extremely polymorphous*, others, that we doubt not are distinct, differ constantly in one or two particulars which experience proves to be of no moment at all in analogous cases. (If it be said that it is not likely the Creator should originate two species with so trifling a difference between them, I would suggest that the marks we define a species by do not *constitute* the species; they are only the convenient 'outward and visible sign of an inward grace,').

One would have more confidence in Gray's grasp of the significance of variation, if he had omitted the above sentence which he placed in parentheses. He continued:

> When we find two . . . representative forms geographically connected by intermediate stations—the differences, such as they are, . . . is a question to be decided either way, with more or less probability, according to our best judgment on the case, but we cannot pretend to decide it with anything like certainty. But if, with the mingling or approximation of the areas we find a shading off of the differences, then it

[1] For a detailed description of this meeting, see "Letters of Asa Gray," Jane Loring Gray, editor (Boston and New York, 1893), I, 117.

[2] "Letters of Asa Gray," II, 380.

[3] *Ibid.*, 454.

[4] For a copy of this letter, written by Asa Gray from Cambridge, Massachusetts, February 21, 1854, the author wishes to thank Dr. M. L. Green, of the Herbarium at the Royal Botanic Gardens, Kew, Surrey, England, where the original letter is deposited.

is far more likely that they all belong to one species. . . .

And this leads me to two points that I must have boggled in my former letter: for as they stand in my mind, I see no real contradiction between them, *viz.* the general and fundamental law of *genetic resemblance*, and the exceptional, *inexplicable* (we should call it impossible antecedently to the fact) origin of *races*, which, once originated, equally follow the law of genetic resemblance, show the strongest tendency to reproduce the parental features or peculiarities,—though this be partly overborne by the tendency to revert to the original type—but more generally obliterated by intermixture of stock.

In the same letter, Gray raised the question of variation:

Unisexual trees, you observe, are not more variable than hermaphrodite ones. Did it ever occur to you that they *should be less variable because* unisexual—the inevitable mingling of stock preventing the continuance of individual peculiarities? And consider, also, how many more plants than is generally thought are subpolygamous or subdioecious,—the stamens more vigorous in one individual, the pistil in another.

The complete letter was sent to Darwin soon after Hooker had received it, according to the following communication which Hooker had from Darwin, written on March 26, 1854. Darwin's closing sentence was especially revealing:

I am particularly obliged to you for sending me Asa Gray's letter; how very pleasantly he writes. To see his and your caution on the species-question ought to overwhelm me in confusion and shame; it does make me feel deuced uncomfortable. . . . I was pleased and surprised to see A. Gray's remarks on crossing, obliterating varieties, on which, as you know, I have been collecting facts for these dozen years. How awfully flat I shall feel, if when I get my notes together on species, etc., etc., the whole thing explodes like an empty puff-ball.[5]

It was in April of the next year that Darwin wrote his first letter to Gray, incidentally stating: "I may premise that I have for several years been collecting facts on 'variation,' and when I find that any general remark seems to hold good amongst animals, I try to test it in Plants."[6] He continued with a request for information regarding Alpine plants. There was no reference made to the above-mentioned letter which Gray had written to Hooker.

Early in 1856, Lyell urged Darwin to write out his views on the origin of species; and in July of that year we learn that Darwin was cautiously sounding out Gray:

It is not a little egotistical, but I should like to tell you (and I do not *think* I have) how I view my work. Nineteen years (!) ago it occurred to me that whilst otherwise employed on Nat. Hist., I might perhaps do good if I noted any sort of facts bearing on the question of the origin of species, and this I have since been doing. Either species have been independently created, or they have descended from other species, like varieties from one species. . . . But as an honest man, I must tell you that I have come to the heterodox conclusion that there are no such things as independently created species—that species are only strongly defined varieties.[7]

A little more than a year was to pass before Darwin wrote Gray a still more significant letter, in which he summarized the theory of natural selection, and requested secrecy:

You will, perhaps, think it paltry in me, when I ask you not to mention my doctrine; the reason is, if any one, like the author of 'Vestiges,'[8] were to hear of them, he might easily work them in, and then I should have to quote from a work perhaps despised by naturalists, and this would greatly injure any chance of my views being received by those alone whose opinions I value.[9]

In this brief paper it is impossible to reproduce more than a part of Darwin's

[5] "Life and Letters of Charles Darwin," Francis Darwin, editor (New York, 1897), I, 403.

[6] This is the first letter Darwin wrote to Gray. See "Life and Letters," I, 420.

[7] *Ibid.*, 437.

[8] Robert Chambers, "Vestiges of the Natural History of Creation" (New York, 1845).

[9] *Journal of the Proceedings of the Linnæan Society* (London, 1859), xxx, 51. For a brief extract, see "Life and Letters," I, 477; also a footnote added by Francis Darwin with reference to the date of this letter, which "Life and Letters" printed as "Sept. 5 [1857]."

letter of September 5, 1857, which, though it contained many closely written pages, Darwin called a "*most* imperfect" sketch, telling Gray that "your imagination must fill up very wide blanks." It contained the first statement of Darwinism to come to the United States; secondly, Gray really had in his possession the conclusive evidence that Darwin had formulated his theory prior to that of Alfred Russel Wallace, whose letter from Ternate was dated February, 1858. Thirdly, this outline of natural selection sent to Asa Gray indicated either that Darwin had confidence in him, or that he wished to protect his hypothesis from being anticipated by Gray. Fourthly, Asa Gray thus had two years to reflect on the implications of natural selection before he undertook to expound and defend it. This gave Gray a distinct advantage in the Darwinian controversy.

Students of the history of American biology, especially those interested in what Darwin regarded as the essence of his theory, will be glad to have easy access to this abstract of his letter, written from his home at The Downs:

It is wonderful what the principle of selection by man, that is the picking out of individuals with any desired quality, and breeding from them, and again picking out, can do. Even breeders have been astounded at their own results. They can act on differences inappreciable to an uneducated eye. Selection has been *methodically* followed in *Europe* for only the last half century; but it was occasionally, and even in some degree methodically, followed in the most ancient times. There must have been also a kind of unconscious selection from a remote period, namely in the preservation of the individual animals (without any thought of their offspring) most useful to each race of man in his particular circumstances. The 'roguing,' as nurserymen call the destroying of varieties which depart from their type, is a kind of selection. I am convinced that intentional and occasional selection has been the main agent in the production of our domestic races; but however this may be, its great power of modification has been indisputably shown in later times. Selection acts only by the accumulation of slight or greater variations, caused by external conditions, or by the mere fact that in generation the child is not absolutely similar to its parent. Man, by this power of accumulating variations, adapts living beings to his wants—may be said to make the wool of one sheep good for carpets, of another for cloth, etc. . . .

I think it can be shown that there is such an unerring power at work in *Natural Selection* (the title of my book), which selects exclusively for the good of each organic being. The elder De Candolle, W. Herbert, and Lyell have written excellently on the struggle for life; but even they have not written strongly enough. Reflect that every being (even the elephant) breeds at such a rate, that in a few years, or at most a few centuries, the surface of the earth would not hold the progeny of one pair. I have found it hard constantly to bear in mind that the increase of every single species is checked during some part of its life, or during some shortly recurrent generation. Only a few of those annually born can live to propagate their kind. What a trifling difference must often determine which shall survive, and which perish!

Now take the case of a country undergoing some change. This will tend to cause some of its inhabitants to vary slightly—not but that I believe most beings vary at all times enough for selection to act on them. Some of its inhabitants will be exterminated; and the remainder will be exposed to the mutual action of a different set of inhabitants, which I believe to be far more important to the life of each being than mere climate. Considering the infinitely various methods which living beings follow to obtain food by struggling with other organisms, to escape danger at various times of life, to have their eggs or seeds disseminated, etc., etc., I cannot doubt that during millions of generations individuals of a species will be occasionally born with some slight variation, profitable to some part of their economy. Such individuals will have a better chance of surviving, and of propagating their new and slightly different structure; and the modification may be slowly increased by the accumulative action of natural selection to any profitable extent. The variety thus formed will either coexist with, or, more commonly, will exterminate its parent form. An organic being, like the woodpecker or misseltoe, may thus come to be adapted to a score of contingencies—natural selection accumulating those slight variations in all parts of its structure, which are in any way useful to it during any part of its life.

Multiform difficulties will occur to every one, with respect to this theory. Many can, I think, be satisfactorily answered. *Natura non facit saltum* [Nature does not make leaps] answers some of the most obvious. The slowness of the

change, and only a very few individuals undergoing change at any one time, answers others. The extreme imperfection of our geological records answers others.

Another principle, which may be called the principle of divergence, plays, I believe, an important part in the origin of species. The same spot will support more life if occupied by very diverse forms. We see this in the many generic forms in a square yard of turf, and in the plants or insects on any little uniform islet, belonging almost invariably to as many genera and families as species. We can understand the meaning of this fact amongst the higher animals, whose habits we understand. We know that it has been experimentally shown that a plot of land will yield a greater weight if sown with several species and genera of grasses, than if sown with only two or three species. Now, every organic being, by propagating so rapidly, may be said to be striving its utmost to increase in numbers. So it will be with the offspring of any species after it has become diversified into varieties, or subspecies, or true species. And it follows, I think, from the foregoing facts, that the varying offspring of each species will try (only few will succeed) to seize on as many and as diverse places in the economy of nature as possible. Each new variety or species, when formed, will generally take the place of, and thus exterminate its less well-fitted parent. This I believe to be the origin of the classification and affinities of organic beings at all times; for organic beings always *seem* to branch and sub-branch like the limbs of a tree from a common trunk, the flourishing and diverging twigs destroying the less vigorous—the dead and lost branches rudely representing extinct genera and families. . . .[10]

J. D. Hooker had been in Darwin's confidence for many years, during which time he had become a believer in natural selection; but, because of the pledge to secrecy, had been forced to retain the creation hypothesis in his writings. Hooker, writing to Gray from Kew, on October 20, 1858, revealed his early acceptance of natural selection:

Most thankful I am that I now can use Darwin's doctrines—hitherto they have been secrets I was bound in honor to know, to keep, to discuss with him in private—& to combat if I could in private—but never to allude to in public, & I had always in my writings to discuss the subjects of creation, variation, etc., as if I had never heard of Natural Selection, which I have all along known & felt to be not only useful in itself as explaining many facts in variation, but as the most fatal argument against 'Special Creation,' & for 'Derivation' being the rule for all species.[11]

Hooker thus told of the embarrassment which Darwin's confidence had caused him. Gray was placed in a similar position, though for a much shorter period. For some time he had been comparing the flora of Japan with that of the United States. It was on December 14, 1858, that he read a notable paper on the distribution of similar species of plants in the two countries. In a footnote, probably added while the paper was going through the press, Gray became specific, but did not reveal that he had received confidential information from Darwin: "The only noteworthy attempt at a scientific solution of the problem . . . is that of Mr. Darwin and (later) of Mr. Wallace. . . . But I am already disposed, on these and other grounds, to admit that what are termed closely related species may in many cases be lineal descendents from a pristine stock."[12]

If it is permissible to draw an inference, it seems clear that the conservative Asa Gray would not have added this note unless he had become convinced, through

[10] *Journal of the Proceedings of the Linnæan Society:* "On the Tendency of Species to form Varieties; and on the Perpetuation of Varieties and Species by Natural Means of Selection," by Charles Darwin, Esq., F.R.S., F.L.S., and F.G.S., and Alfred Wallace, Esq. Communicated by Sir Charles Lyell, F.R.S., F.L.S., and J. D. Hooker, Esq., M.D., V.P.R.S., F.L.S., etc. These letters were read on July 1, 1858. First came a letter signed by Lyell and Hooker. Enclosures were: (1) Extracts from the Ms. of Charles Darwin, sketched in 1839, copied in 1844; (2) An abstract of the letter from Darwin to Gray (October, 1857); and (3) The essay by Wallace, written in February, 1858, "for the perusal of his friend and correspondent Mr. Darwin, and sent to him with the expressed wish that it should be forwarded to Sir Charles Lyell, if Mr. Darwin thought it sufficiently novel and interesting."

[11] Gray Correspondence, Gray Herbarium, Cambridge, Massachusetts.

[12] "Memoirs," American Academy of Arts and Sciences, New Series (Cambridge and Boston, 1859), VI, Part 1, 443.

Darwin's letter of September 5, 1857, of the genetic continuity of species.

Publication of the "Origin of Species" by Appleton

The confidence which impelled Charles Darwin to reveal his precious secret to Asa Gray readily explains why he should turn to him to supervise the publication of the "Origin of Species[13] in the United States. Darwin's first letter concerning this business was written after John Murray, of London, had brought out the first edition of the "Origin" in 1859. It tells of the remarkable sale of the entire edition on the first day, and of his ambition for an American edition.

> I should for several reasons be very glad of an American Edition; I have made up my mind to be much abused; but I think it of importance that my notions should be read by intelligent men, accustomed to scientific arguments though *not* naturalists. . . .
>
> The first Edition of 1250 copies was sold on the first day, and now my Publisher is printing off as *rapidly as possible* 3000 more copies. I mention this solely because it renders probable a remunerative sale in America. I should be infinitely obliged if you could aid an American Reprint, and could make, for my sake and Publishers, any arrangement for any profit.[14]

It might be well, at this point, to note the financial arrangement with Murray, which was generous and possibly suggestive: "My terms with Murray are that I receive ⅔ of Profits, & he ⅓."[15]

Asa Gray took steps to have the Boston publishers, Ticknor and Fields, bring out the "Origin of Species," as this letter to Darwin records:

> You have my hurried letter telling you of the arrival of the remainder of the sheets of the reprint; and of the stir I had made for a reprint in Boston. Well, all looked pretty well, when, lo, we found that a second New York publishing house had announced a reprint also! I wrote then to both New York publishers, asking them to give way to the *author* and his reprint of a revised edition. I got an answer from Harpers that they withdrew—from the Appletons that they had got the book *out* (and the next day I saw a copy); but that, 'if the work should have any considerable sale, we certainly shall be disposed to pay the author reasonably and liberally.'[16]

The subject of royalties is of interest to every author, and the custom of American publishers before the adoption of the international copyright law was that each paid as he saw fit. It has been maintained that American publishers treated English authors at that time the same as they did those of the United States. This widely accepted belief may be traced to the following statement of John Fiske: "The Appletons . . . always paying a royalty to the authors, the same as to American authors, in spite of the absence of an international copyright law."[17]

However, the following facts in reference to Darwin and Gray will show that Fiske's statement was not correct.

Darwin, writing to Asa Gray on May 22, 1860, said:

> Again I have to thank you for one of your very pleasant letters of May 7th, enclosing a very pleasant remittance of £22. I am in simple truth astonished at all the kind trouble you have taken for me. I return Appleton's account. For the chance of your wishing a formal acknowledgment I send one. If you have any further communication to the Appletons, pray express my acknowledgment for [their] generosity; for it is generosity in my opinion. I am not at all surprised at the sale diminishing; my extreme surprise is at the greatness of the sale. No doubt the public has been *shamefully* imposed on! for they bought the book thinking that it would be nice easy reading. I expect the sale to stop soon in England, yet Lyell wrote to me the other day that calling at Murray's he

13 Publications of the "Origin of Species" by Appleton: 1860; New Edition, 1868; Fifth Edition, 1870; Sixth Edition, 1890; New Printing, 1892; Authorized Edition, 1896; New Printing, 1900; Sixth Edition, 1926.

14 Gray Correspondence, Gray Herbarium. See, also, "Life and Letters," II, 39.

15 Gray Correspondence, Gray Herbarium, Darwin to Gray, January 28 [1860].

16 "Letters of Asa Gray," II, 456. See, also, "Life and Letters," II, 64–65.

17 John Fiske, Edward Livingston Youmans (New York, 1894), 111.

heard that fifty copies had gone in the previous forty-eight hours.[18]

The following statement, mentioned in the above letter, was sent by Appleton to Gray; then forwarded to Darwin, who returned it to Gray:[19]

Asa Gray for Mr. Darwin.
DARWIN
Statement of the Sale of "Origin of Species" to May 1st, 1860.

On hand last account,		....
Printed Jan'y /60		1500
Feb'y /60		500
Mch /60		500
		2500
1750 Sold, at 5% on		$1.25
On hand this date,	250	
In hands of Booksellers,	300	550
Given away,		200
Sold to date,		1750
		2500
Copyright amounting to	$109.37	
	= £22.	00

A review of the Appleton-Gray correspondence at the Gray Herbarium showed that Gray received a royalty of 10 per cent. on the books they published for him over the period from 1877 to 1885.[20]

Darwin was eager for a second American edition, and that it should contain important corrections—especially about the "bear" story:

In the first edition one reads on page 184: 'In North America the black bear was seen by Hearne swimming for hours with widely open mouth, thus catching, like a whale, insects in the water. Even in so extreme a case as this, if a supply of insects were constant, and if better adapted competitors did not already exist in the country, I can see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale.' In a second edition the whole second sentence of this quotation was expunged, and in the first sentence a qualifying 'almost' was inserted after 'catching.'[21]

Appleton's attitude is revealed in this unpublished letter:[22]

New York, Feb. 17/60.

Prof. Asa Gray,
Dear Sir:

Your favor of 15th is at hand. We can't say what we can do respecting the notes and additions till we see them but we shall be anxious to make our edition conform to any future English Edn.

You are under a mistake in supposing that new matter unpublished in England secures a copyright in this country if written by Mr. Darwin—on the contrary if the entire work had never been published in England and first appeared here no copyright would hold in this country as no one can hold a copyright here for what he has written unless he be a citizen of the U. S.

We proposed to ourselves to pay 5% on retail price as suggested in your letter, as there is no reason why a work without any legal rights, should pay the same as one that is secured by law.—We desire to act liberally altho' we printed the work after it had reached this country some little time; not having received even early sheets which is usual when any payments are made. We regret very much there is no protection to the foreign author, think it a monstrous shame, but we are obliged to take things as they actually exist.—We are quite willing if it would be agreeable to Mr. Darwin to send him a check for 50 £ Stg. and very likely that will be as much as he could receive by the sales.

We remain,
Very respectfully,
D. Appleton & Co.

The following letters suggest that the Appleton Company were evidently annoyed with Darwin's requests for minor changes:

[18] Gray Correspondence, Gray Herbarium. See, also, "Life and Letters," II, 104; and "Autobiography and Letters" (New York, 1893), 248.

[19] Gray Correspondence, Gray Herbarium.

[20] *Ibid.*

[21] Paul B. Victorius, "A Sketch of the 'Origin of Species' ": *The Colophon*, Original Series (New York, 1932). The writer has been given permission by Mr. Victorius to quote from this article.

[22] Gray Herbarium, Cambridge, Massachusetts.

On May 7, 1866, Gray wrote Darwin regarding the new edition of the *Origin,* saying that he had heard nothing from the Appletons for years—"the sale, I suppose, has gone on slowly, but they have made no returns. . . . I will write to the Appletons asking them in the first instance if they will bring it out, and allow you the paltry 5% on sales; and if they decline I would arrange with a Boston publisher, and have the work brought out in a handsome form, as a standard author."

On July 3, of the same year, Gray again wrote to Darwin:

I should have earlier replied to yours of 25 May. But the Appletons do not behave well. I wrote them on receiving your letter, June 9. They waited till 18th to reply, as enclosed. I wrote . . . urged the impracticability of altering the plates and your aversion to that, as that would be unjust to you—said we wanted now a neat and permanent library edition.—

No reply to that. But yesterday I wrote saying I now had some sheets & asked . . . if they would object to my offering the sheets to some other publisher.

I think it likely they will play *dog in the manger*—for which part they have advantages,—as they might reprint your additions & issue, with their old stereotype pages, without regard to appearance or decency, & so spoil the venture of any other publisher. At least the fear of it might deter any other publisher. We shall soon see if I do them injustice.

Gray, keeping Darwin posted as to publication developments, wrote to him twice during August, 1866—on the 7th and the 27th. In the first of these letters he said that "Appleton has, at my request, returned the sheets I had sent him. As he persisted in the idea of making what he called the *essential* alterations on his old stereotype plates, I thought that I could not for any petty pecuniary advantage, even connive at such doings." On the 27th, apparently disgusted with Appleton's methods, he wrote:

I have yours of the 4th inst. . . . you rightly infer that there is no hope at present for an American reprint, unless you agree to fall in with Appleton's shabby ways—which I think you will not be tempted to do.

But I am encouraged to think that I can make a *good arrangement* with Messrs. Ticknor & Fields, of Boston, to bring out the new book, & allow Author 12%. I shall confer with Mr. Fields.[23]

The review of the evidence in regard to the publishing of the "Origin of Species" by Appleton indicates that they paid Charles Darwin, through Asa Gray, 5 per cent. on the first edition, and *not* the usual 10 per cent. royalty, as Fiske stated. We have thus far been unable to locate any documented statements dealing with subsequent publications. However, there is the letter quoted above, from Appleton to Gray, and the postscript added by Gray, suggesting that there had been negotiations in reference to the publication of the second edition.

Asa Gray had forwarded Appleton's letter to Darwin, with this comment:

Feb. 20, 1860.

MY DEAR DARWIN:

I got this to-day. I send Appletons, now, the sheets of ed. 2, and your additions appended in their places. I promise the Historical Preface next week, and I put it in their hands—trusting to their promise of 5 [prints] and to their honor for more if they are not molested by reprinters, which we shall keep off. . . . The offer of check for £50—(which I might send to Mrs. Darwin for pin-money, since you scorn it) tempts me,—but I think it wiser to wait and hope for more.[24]

At the close of a letter to Gray, written on September 25, 1860, Darwin added: "P.S.—Please observe that if the Appletons lose by the second Edition barely selling, I should PREFER repaying the money they have paid me."[25] Apparently the Appleton Company refused to make a definite contract; and here the evidence on what was paid Darwin as royalty on the "Origin of Species" closes.

This brief comparison of the first and

[23] These letters were copied from the originals at the Gray Herbarium.

[24] *Ibid.*

[25] *Ibid.*

second American editions lets the secret out, and confirms Gray's fears:

The second American edition was published during the summer of 1860. It appeared after the second and before the third English edition. This second American edition is of considerable bibliographic and scientific interest, because it contains matter never before published. The title-page describes it properly as 'A New Edition, Revised and Augmented by the Author.' The edition contains a preface here first published and a historical sketch. Although the second American edition was published at a sufficient interval after the second English edition to include all the corrections and alterations that appeared in the latter, one finds nevertheless the original bear story, which appears only in the first and not in the second English.[26]

We know that Darwin, as he had anticipated, was properly ridiculed and "much abused" for his "bear" story, which was carrying the influence of natural selection much too far. Of Harvey's criticism, he remarked that there would be: "no more difficulty than man has found in increasing the crop of the pigeon, by continued selection, until it is literally as big as the whole rest of the body."[27,28]

THE NORMAL BURNING OF GASEOUS EXPLOSIVE MIXTURES

II. ENGINE FLAMES, THEORIES AND APPLICATIONS

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Flames in Engine Cylinders

A text-book by Taylor and Taylor[31] on "The Internal Combustion Engine," published in 1938, includes a bibliography of about 540 references to reports bearing on engine operation. Of these at least one fifth are concerned primarily with the combustion process and the changes in this process which result when the operating conditions are varied. A brief review of such a broad field is necessarily limited to generalities. However, these may serve to illustrate the trends which past research on combustion in the engine cylinder has followed, as well as the complexity of the problem, and to some extent, the present state of our knowledge of the burning process.

It may not be amiss to enumerate, first, the principal sources from which published information on engine studies may now be expected. Very little material has appeared recently from the larger European countries, since all information pertaining to engines is considered of military importance. The one notable exception has been the research division of the Royal Dutch Shell Corporation. In this country the National Advisory Committee for Aeronautics sponsors a wide variety of combustion research at Langley Memorial Aeronautical Laboratory, at other government laboratories and at several universities. Some of our schools, such as Massachusetts Institute of Technology and Pennsylvania State College, are actively engaged in engine research. Many other universities have made contributions, and the list may reasonably be expected to increase rapidly under the stimulus

[31] C. F. Taylor and E. S. Taylor, "The Internal Combustion Engine," Scranton: International Text-book Company, 1938.

[26] Victorius, *The Colophon*.

[27] "More Letters of Charles Darwin," Francis Darwin, editor (New York, 1903), I, 162.

[28] The difficulties of obtaining a complete account of "How Darwinism came to the United States" are doubtless evident to the reader. Any corrections and additional facts will be welcomed by the author.

of the current nation-wide emphasis on aeronautics. Among the industries, there have been notable contributions from various producers of fuels and fuel dopes, and of aeronautic and automotive engines and accessories.

Studies of flame and combustion in the engine cylinder generally require that provision be made for observing both the rise in pressure during an explosion and the progress of the flame. As a result of the nature and behavior of our common motor fuels, engine studies are usually concerned, at least to some extent, with detonation or knock, which Boyd[32] has aptly called "the cancer of engine combustion." Since the very rapid burning during knock is accompanied by an exceedingly rapid rise in pressure, the occurrence of knock is clearly evident on both the pressure and the flame records.

A brief discussion of pressure indicators in general has been presented in a previous section. Those suitable for use in an engine cylinder must be sturdy to withstand the repeated shocks of continuous operation and must be adequately cooled. The design, theory and applications of a number of indicators which have been used with varying degrees of success are described in a book by De Juhasz[33] on "The Engine Indicator."

Flame travel in engine cylinders. The progress of the flame has been observed by using ionization gaps[34,35,36] or through windows which have varied in size from small ones giving very local views of the flame to cylinder heads made entirely of transparent material. Various stroboscopic devices, synchronized with the engine, have been used in conjunction with the windows to restrict the view to a small fraction of each cycle. In most cases, however, the travel of the flame has been recorded on a moving film, either continuously or in the usual frame by frame manner of the ordinary motion picture camera.

Recently special cameras, in which multiple lenses are rotated with the film, have been developed. One of these, described by Withrow and Rassweiler,[37] gives 5,000 photographs per second at an engine speed of 2,000 rpm. Stated in another way, this camera was used to take 30 separate photographs of the entire combustion chamber during the 72° of crank angle embracing the ignition and subsequent combustion of the charge.

Flame pictures of knockless combustion show that the progress of the flame from ignition to complete inflammation is continuous, and simultaneous pressure records are correspondingly smooth and free from any abrupt changes. Such records also show[38] that the flame speed increases almost as fast as engine speed and that the combustion process therefore transpires in roughly the same number of degrees of crank rotation, regardless of engine speed. A plausible interpretation seems to be that the amount of local turbulence in the charge is approximately proportional to engine speed. The more vigorous the mechanical stirring of the gases in the neighborhood of the flame front, the more rapid is the mixing of burned, burning and unburned particles, so that the opportu-

[32] T. A. Boyd, *Soc. Automotive Engineers Jour.*, 45: 421–432, 1939.

[33] K. J. De Juhasz, "The Engine Indicator," New York: Instruments Publishing Company, 1934.

[34] K. Schnauffer, *Soc. Automotive Engineers Jour.*, 34: 17–24, 1934.

[35] H. Rabezzana and S. Kalmar, *Automotive Industries*, 72: 324–329, 354–357 and 394–397, 1935; *ibid.*, 81: 534–542 and 632–639, 1939.

[36] W. A. Mason and K. M. Brown, *Automotive Industries*, 72: 582–584, 1935.

[37] G. M. Rassweiler and L. Withrow, *Indust. and Engineering Chem.*, 28: 672–677, 1936; L. Withrow and G. M. Rassweiler, *Soc. Automotive Engineers Jour.*, 39: 297–303, 1936.

[38] C. F. Marvin, A. Wharton and C. H. Roeder, *Technical Report No. 556*, Nat. Advisory Committee for Aeronautics, 1936.

nity for fruitful collisions, and consequently the flame speeds, increase. For the same reason the turbulence which is always present in an engine cylinder is thought to account for the fact that, for comparable explosive mixtures the speed of flame in space is greater in the engine than in bombs.

Most flame photographs, and particularly those of the entire combustion chamber, show both the irregular pattern of the flame front produced by local turbulence and general deviations from symmetry of the whole flame, resulting from mass motions of the entire unburned charge as induced during the intake stroke.

The flame pictures taken after the flame has traversed the entire charge show the greatest luminosity in portions which were burned first. There thus appears to be a close relation between the intensity of the actinic light and the temperature of the burned gas, which has also been shown to be highest in the first part of the charge to burn.[39] Experimental proof of the existence of such a temperature gradient throughout the burned gas in a bomb was first given in 1906 by Hopkinson,[40] later demonstrated theoretically by Mache,[41] and evaluated quantitatively for the specific case of an ozone-oxygen explosion by Lewis and von Elbe.[42]

Correlation of flame and pressure records. Rassweiler, Withrow and Cornelius[43] have attempted to correlate high-speed motion pictures with simultaneous pressure records, giving special attention to the effects of changing the mixture ratio, spark position and throttle opening. This analysis leads to the conclusion that both the fraction of the volume and the fraction of the mass of charge which is inflamed at any instant can be computed from the pressure record alone, with an accuracy which is comparable with that of calculations based on combustion chamber dimensions and flame photographs.

Knocking combustion. In the case of combustion under knocking conditions, both the flame and the pressure records are similar to those under non-knocking conditions during the initial stages of the burning. Then, depending upon the composition of the explosive mixture and the operating conditions, there appears a sudden change in the nature of the flame photographs and in the pressure within the cylinder. Both these changes indicate an enormous increase in the rate of combustion, accompanied by vibratory motions within the gases, which, in turn, are transmitted to and through the walls of the combustion chamber and thence to the surrounding atmosphere in the form of audible sound waves, from which the knock derives its name.

The vibrations within the cylinder also cause vibration of the moving parts of the pressure indicator, so that the pressure records of a knocking combustion show, first, a sudden increase in the rate of pressure rise, followed by an interval of periodic fluctuations having gradually decreasing amplitudes. It has been shown[44] that the frequency of the waves in the flame photographs corresponds with the frequency of the vibrations on the pressure record. Further it has been shown that the frequency of the pressure waves within the cylinder is the same as the frequency of the audible

[39] G. M. Rassweiler and L. Withrow, *Soc. Automotive Engineers Jour.*, 36: 125–133, 1935.

[40] B. Hopkinson, *Proc. of the Royal Soc. of London*, A77: 387–413, 1906.

[41] H. Mache, "Die Physik der Verbrennungserscheinungen." Leipsig: Veit and Company, 1918.

[42] B. Lewis and G. von Elbe, *Jour. Chemical Physics*, 2: 537–546, 1934.

[43] G. M. Rassweiler, L. Withrow and W. Cornelius, *Soc. Automotive Engineers Jour.*, 46: 25–48, 1940.

[44] L. Withrow and G. M. Rassweiler, *Automobile Engineer*, 24: 281–284, 1934.

sound outside the engine.[45] The observed frequencies varied from 3,000 to 6,000 cycles per second, depending upon the dimensions of the combustion chamber and the temperature of the burned gas.

Because of the extreme rapidity of the burning after the knock has begun, only flame records taken at very high film speeds show that the subsequent inflammation of the charge does not take place simultaneously throughout all the remaining unburned gas. Withrow and Rassweiler[46] interpret their photographs to mean that auto-ignition occurs at a point ahead of and well separated from the flame, without much change in the form and position of the original, normal flame front. They conclude that "perhaps in all knocking explosions, the knock is definitely not a result of a sudden increase in the velocity of the advancing flame." From other original photographs, Rothrock and Spencer[47] are led to the belief that "although auto-ignition ahead of the flame front may occur in conjunction with severe knock, probably it is not necessary nor does it always occur with knock." The latter authors also see evidence in their pictures that reaction is not completed in the flame front and suggest that in some cases knock may occur in the burned gas as a result of the sudden liberation of the energy remaining after the initial passage of the flame.

Stansfield and Thole[48] suggest that three types of detonation may be possible, namely, true knock, auto-ignition, and pre-ignition, while Boerlage and his co-workers[49] distinguish between "pinking" and knocking. It is hoped that photographs of knocking combustion taken at still higher speeds may soon be available to answer some of the outstanding questions concerning the physical nature of the very rapid burning.

Radiation from engine flames. Other important information has been obtained by observations through windows opening into the combustion chamber. Among such studies may be mentioned various attempts to determine the radiation characteristics of both burned and unburned gas and the movements of the gases by schlieren photography.

In 1924, Midgley and McCarty[50] studied the relative effects of various operating conditions upon the total energy radiated from the combustion chamber through a quartz window and the slot of a timing stroboscope, by measuring the current output of a thermopile upon which the radiation was focused. The results for a given fuel showed that the mixture proportioned to give maximum power radiated the most energy, whether there was knock or not, and that, for a given piston position, energy was radiated at a greater rate during a knocking than a non-knocking combustion.

More detailed information concerning the mechanism of the processes in progress prior to the arrival of the flame and at all stages subsequent to the passage of the flame front has been obtained by studying both the absorption and emission spectra. Spectroscopes have been used in the ultra-violet and visible ranges, and the spectral distribution in the infrared was studied by the use of

[45] C. E. Grinstead, *Jour. Aeronautical Sciences*, 6: 412–417, 1939.

[46] G. M. Rassweiler and L. Withrow, *op. cit.* in reference 37.

[47] A. M. Rothrock and R. C. Spencer, *Technical Report No. 622*, Nat. Advisory Committee for Aeronautics, 1938.

[48] R. Stansfield and F. B. Thole, *Engineering*, 130: 468–470 and 512–514, 1930.

[49] G. D. Boerlage and W. J. D. van Dyck, *Jour. Royal Aeronautical Soc.*, 38: 953–986, 1934; G. D. Boerlage, J. J. Broeze, H. van Driel and L. A. Peletier, *Engineering*, 143: 254–255, 1937.

[50] T. Midgley and H. H. McCarty, *Soc. Automotive Engineers Jour.*, 14: 182–185, 1924.

appropriate filters. There is space for but a brief résumé of the conclusions from such studies.

Nearly all the energy radiated by the flame in an engine is in the infrared,[51] and apparently arises from the formation of H_2O and CO_2. In a normal combustion, radiation from these two compounds begins upon the arrival of the flame front and continues for some time thereafter, thus pointing to continued reaction. The duration of the continued reaction is much shorter when knock occurs. Although there is a great variation in the total energy radiated during a single cycle and under different operating conditions, the spectral distribution shows only small changes over a wide range of these conditions. The significance of the observed changes in distribution is not known.

The research groups of the General Motors Corporation have made valuable contributions[52] concerning both absorption and emission spectra. Among these reports the following conclusions may be found.

The absorption spectra of the unburned charge in that part of the combustion chamber where knock occurs show that formaldehyde is always present under knocking conditions. This compound is also found in the absence of knock, but its formation may be avoided by changing the operating conditions so as to reduce sufficiently the tendency to knock. The addition of tetraethyl lead does not affect the concentration of formaldehyde appreciably, while addition of enough aniline to suppress knock completely, decreases the formaldehyde concentration. The formaldehyde bands disappear when knock is stopped by increasing the concentration of fuel in the explosive mixture or by retarding the spark. Formaldehyde introduced with the intake air did not induce knock, even though a portion was shown to remain intact until the time of knock. Many other absorption bands are present prior to knock, but the molecules responsible for them have not been identified.

The emission spectra observed when hydrocarbons are burned either in a burner or in an engine cylinder show the characteristic bands of CH and C_2. However these bands are absent in the region behind the flame front, suggesting that the breakdown of the hydrocarbon is completed in the flame front. This does not necessarily mean, however, that the formation of H_2O and CO_2 proceeds to equilibrium in the front. Bands of OH radicals were found in the ultraviolet for both the flame front and the afterglow, and bands of HCO, while present in the front, are entirely absent in the afterglow.

In the knocking zone the intensity of the CH and C_2 bands was much lower in the knocking than in non-knocking explosions. Thus it is suggested that the hydrocarbon may be at least partly broken down by preflame reactions prior to the inception of knock. When tetraethyl lead was used to prevent knock, the intensity of the CH and C_2 bands increased, suggesting that the lead may inhibit preflame decomposition of the fuel.

Application of the spectral line reversal method of measuring the temperatures attained during explosions in the engine cylinder[53] shows that, after inflammation is complete, the temperature difference in the cylinder may exceed 300° C. When knock is present higher temperatures are reached earlier in the

[51] C. F. Marvin, F. R. Caldwell and S. Steele, *Technical Report No. 486*, National Advisory Committee for Aeronautics, 1934.

[52] L. Withrow and G. M. Rassweiler, *Indust. and Engineering Chem.*, 25: 923–931 and 1359–1366, 1933; *ibid.*, 26: 1256–1261, 1934.

[53] G. M. Rassweiler and L. Withrow, *op. cit.* in reference 39.

cycle, the subsequent rate of cooling is greater, and the exhaust temperatures are lower. It is of interest to note in passing that the maximum temperature observed in an engine with a compression ratio of only 4.4:1 exceeded 2,500° C., more than 1,000° C. above the melting point of the material constituting the combustion chamber.

Combustion in compression-ignition engines. Studies of combustion in the cylinders of compression-ignition engines are in general more complicated and not so far advanced as those in the more common spark-ignition type. The additional complications arise in connection with the injection of the fuel, its mixing with the previously compressed air and the auto-ignition of the resulting mixture.

Since ignition starts, not at a selected point, but in whatever place or places the necessary conditions of temperature and composition are first attained, the rate at which combustion proceeds must depend to a greater extent upon the state and distribution of the fuel than upon such characteristics of the mixture as transformation velocity and expansion ratio.

It is beyond the scope of this review to discuss the progress which has been made in studying the processes of fuel injection and mixing. This has already been done in Chapter 7 of "The Internal Combustion Engine,"[54] in which the original reports are also mentioned.

Other practical problems which must be solved to insure the satisfactory operation of a compression-ignition engine again involve control of the combustion process. Actually in this case control must be exercised over two closely related processes.

The first of these involves the delay period between the start of injection and the start of combustion, while the second involves the control of knocking after ignition has occurred. Since the delay period is not greatly affected by such factors as fineness of the fuel spray or the volatility of the fuel, but instead is largely dependent upon the temperature and pressure prevailing during the early part of the injection process, as well as upon the chemical characteristics of the fuel, it seems probable that during this period the fuel undergoes chemical changes producing materials which auto-ignite more readily than the original fuel. If the delay period is long there is greater chance for such materials to accumulate, so that auto-ignition may subsequently take place simultaneously at a great many places throughout the combustion chamber. Such conditions closely parallel those which exist in a spark-ignition engine just prior to knock. It therefore becomes apparent that a short delay period is of great importance if excessive rates of pressure rise are to be avoided.

The control of knock in compression-ignition engines is thus largely a question of controlling the delay period. This period, and also the tendency to knock, may be decreased by increasing the compression ratio, inlet air temperature, the initial pressure of the air in the cylinder (as by supercharging) and the temperature of the combustion chamber walls where the jet of fuel tends to impinge.

Theories of Flame Propagation

There have been numerous attempts to derive, from theoretical considerations, an equation by which transformation velocity can be calculated from known thermal properties of the burned and unburned mixtures. The earliest of these, proposed by Mallard and Le Chatelier,[55] was based on the primary assumption that heat from the flame was conducted to the ad-

[54] C. F. Taylor and E. S. Taylor, *op. cit.*

[55] F. E. Mallard and H. L. Le Chatelier, *Annales des Mines*, 4: 274, 1883.

jacent unburned gas until its temperature was raised to the "ignition temperature," when it in turn became inflamed. Subsequently this theory was modified and extended by Jouguet,[56] Nusselt,[57] Daniell,[58] and others, each treatment retaining the assumption that the gas to be burned must be first raised to its "ignition temperature" by direct conduction of heat from the flame.

More recently Lewis and von Elbe[59] proposed that "flame propagation is governed by diffusion of active atoms and radicals into the unburned mixture, which gives rise to chemical reaction there in a far more efficient way than would be possible purely by heat transfer." The working hypothesis of this theory is that "the sum of the thermal and chemical energy per unit mass in any elementary layer between the unburned and burned phases remains sensibly constant." A solution of the problem along these more complicated lines, involving both reaction kinetics and heat transfer, is at present possible only when other daring approximations are made. Such a solution has been made for the particular case of explosions in ozone-oxygen mixtures, where the calculated values of transformation velocity are of the same order of magnitude as the experimental values. In addition the analysis provides information as to the structure of the reaction zone, that is as to the gradients of temperature, concentration, and reaction rate. The calculated thickness of the reaction zone is of the order 10^{-3} to 10^{-4} cm.

[56] E. Jouguet, *Comptes Rendus*, 156: 872–875, 1913; *ibid.*, 168: 820–822, 1919; *ibid.*, 179: 454–457, 1924.

[57] W. Nusselt, *Zeitschrift des Vereines Deutsches Ingenieure*, 59: 872–878, 1915.

[58] P. J. Daniell, *Proc. Royal Soc. of London*, A126: 393–405, 1930.

[59] B. Lewis and G. von Elbe, "Combustion Flames and Explosions of Gases," pp. 211–219. London: Cambridge University Press, 1938.

None of the theoretical treatments of flame propagation may be considered adequate for the calculation of usable values of transformation velocity. This is not surprising in a problem of such complexity, since some of the complicating features may not yet have been discovered and since others are poorly understood. As examples, the kinetics of the reactions are in many cases obscure, and the question of the continued evolution of energy within the flame front is still in dispute.

In addition to the above mentioned attempts to derive theoretical expressions for transformation velocity, there have been efforts to formulate certain "laws of flame speeds" of an empirical nature, based on available experimental data. Among these may be mentioned the suggestions of Payman and Wheeler[60] and of Stevens.[61] The former stated that "given two or more mixtures of air or oxygen with different individual gases, in each of which the speed of propagation is the same, all combinations of mixtures of the same type, that is all containing excess of oxygen, or all containing excess of combustible gas, propagate flame at the same speeds, under the same conditions of experiment." In later interpretations the proponents of this "law" elaborated upon it by stating that "any addition of incombustible gas, inflammable gas or oxygen to a mixture of inflammable gas and oxygen in combining proportions has a retarding effect upon the speed of uniform movement of flame proportional to its specific heat" and that "the time taken for pressure within a spherical vessel to attain its maximum . . . coincides with the time taken for flame to reach the boundary of the vessel, except in very slowly moving flames."

[60] W. Payman and R. V. Wheeler, *Transactions* of the Chemical Society, 121: 363–379, 1923.

[61] F. W. Stevens, *Technical Report No. 176*, Nat. Advisory Committee for Aeronautics, 1923.

Bone and Townend[62] object that the "law" and its corollaries imply that combustion is complete in the flame front and that either dissociation does not affect flame speed or that the degree of dissociation is unaffected by dilution with inert gas or excess of one reactant. They present data for mixtures of hydrocarbons, hydrogen and oxygen which appear to deviate from the "law" and state that "whatever measure of truth there may be in Payman and Wheeler's conclusions in regard to particular instances, they are not generally applicable to gaseous explosions, and therefore can not be vested with the authority of a natural law."

As a result of all of his work with gaseous explosions Stevens concluded that, within the limits of his experimental error, the transformation velocity was directly proportional to the mass action product of the active constituents in the original mixture. More recent determinations by the bubble method,[63] yielding values of S_t believed to be of higher accuracy, show much larger departures from this relation than did the results of Stevens. It therefore appears that the relation is an approximation which fails to take account of at least some of the factors which influence transformation velocity. One of its most apparent shortcomings is that it yields a maximum value of S_t at exact chemical equivalence, while the observed maximum always occurs in the presence of some excess of fuel.

A great many experimental studies have been made of the molecular kinetics of reactions between gaseous fuels and oxygen. Many of the results of such studies may be explained on the basis of the theory of chain reactions. A chain reaction is one in which one kind of active atom or radical, called a chain carrier, effects the formation of a large number of product molecules due to its regeneration. Thus the complete picture on a molecular scale of the reaction of fuel and oxygen can be represented in detail only by a group of chemical equations, many of which yield products which are so active and so short lived that they are not found at all in the final products of the reaction, and therefore do not need to appear in the stoichiometric equation representing the overall reaction.

The progress which has been made with the chain theory of reactions is reviewed by Lewis and von Elbe[64] in the first four chapters of their book. Such treatment deals largely with specific instances, which are too numerous to recount here. Despite the fact that real progress has been made, it seems at present that much additional evidence is needed to establish a comprehensive picture of oxidation on a molecular scale.

It is hoped that the present lack of generally applicable postulates concerning the mechanism and rate of gaseous explosive reactions has been sufficiently emphasized in the material which has been preesnted. Such a situation has doubtless hampered, but by no means prevented progress in technical applications of the combustion process.

Some Technical Applications of Combustion Research

Most of the applications of combustion research have been referred to, either directly or by implication, in previous sections of this report. One important group of these is concerned with the prevention of unwanted explosions, with a view to the reduction of accidental hazards in mines and in industry.

[62] W. A. Bone and D. T. A. Townend, "Flame and Combustion in Gases," London: Longmans, Green and Company, 1927.

[63] E. F. Fiock and C. H. Roeder, *Technical Report No. 532*, Nat. Advisory Committee for Aeronautics, 1935.

[64] B. Lewis and G. von Elbe, *op. cit.* in reference 59.

Other general applications of gaseous explosive reactions occur in domestic and industrial heating devices and in internal-combustion engines.

Since the earliest progress was made in the field of safety, it is logical to begin with the applications in this field. Probably the surest way to prevent an explosion is to so control the concentration of fuel in the atmosphere that the resulting mixture never becomes combustible. A first step in such a process is obviously the determination of the limits of flammability. Once these and the possible rates of formation of gaseous fuel are known, it is usually a routine problem for the ventilation engineer to avoid the formation of a combustible mixture.

In many instances, such as arise in the handling and storage of flammable liquids, it is not practicable to avoid at all times the formation of explosive mixtures. It then becomes desirable to reduce the chance of accidental ignition to a minimum. That this effort has not always been successful is illustrated by such well known disasters as those which destroyed the stratosphere balloon Explorer I, and the Zeppelin Hindenburg, and that which recently damaged an oil tanker in dock on the east coast.

The invention of the Davy safety lamp has already been mentioned. By merely inserting a wire gauze between the flame of the lamp and the explosive mixture which often occurred in poorly ventilated mines, this device in effect removed an ever-present source of ignition. It is of course impossible to make any reasonable estimate of the number of mine explosions which have been averted by the use of the safety lamp, or of the number of lives which would have been lost without it.

Flame traps of various sorts, operating on the same general principle as the safety lamp, have been used to prevent the travel of flame along pipes and tubes which convey explosive mixtures or which might accidentally become filled with such mixtures.

In the absence of all external sources of ignition, it is also important to know whether or not there is a possibility of spontaneous ignition in the vapor phase adjacent to a flammable liquid. Therefore many attempts have been made to determine, experimentally, the lowest temperatures at which such mixtures will burst into flame. However, as previously stated, the experimental methods have been more satisfactory for comparative than for absolute results. It may be that in both the experimental and practical cases some such factor as surface condition may be of controlling importance, and that an explosion in a particular tank might result from spontaneous ignition when the temperature of the surroundings was lower than any which had produced ignition of the same explosive mixture in other containers.

The large number of applications of gaseous explosive reactions for the direct production of heat are so familiar that enumeration would be entirely superfluous. The problems involved are those of the stationary flame. More specifically these problems are concerned with the relation of flame and burner, that is with the matching of the flame and burner to the requirements of the application.

Diffusion flames, in which the rate of liberation of energy is limited by the speed of mixing of the fuel and oxygen, produce less heat per unit area than Bunsen-type flames consuming fuel at the same rate. Flame speeds play such a minor part in determining the shape and behavior of the diffusion flame that they need scarcely be considered in connection with such flames.

On the other hand, in burners in which the fuel and oxygen or air are pre-mixed, the transformation velocity is of primary importance, since it fixes the limits over which the rate of flow

of the explosive mixture through a given port can be varied without blow off or flash back. Most appliances using gas flames provide for variation in the ratio of fuel to oxygen as well as in the velocity of the mixture. Since transformation velocity decreases as the composition is varied in either direction from the optimum, the limits of stable operation are rapidly narrowed by such changes in the mixture ratio. Thus knowledge of the transformation velocity and its variation with composition is highly desirable in any attempt at burner design.

A more complete discussion of the problems of stationary flames has been presented by Smith,[65] and further elaboration is not necessary here.

The application of the gaseous explosive reaction as a source of power in internal combustion engines has had the most profound effect upon the life of every one, particularly in this country. Past, as well as future efforts have been and logically should be concentrated upon more efficient control and use of the combustion process. At present there is considerable emphasis on the search for new fuels having less tendency to knock than those commonly available.

[65] F. A. Smith, *Chem. Reviews*, 21: 389–412, 1937.

CONCLUSION

From what has been presented, it is probably apparent that a vast amount of painstaking research has been done in the field of combustion. Yet it may truthfully be said that not a great deal is actually known of the highly complex mechanism, on a molecular scale, by which the chemical energy latent in the fuel is converted into usable mechanical energy. This does not mean, however, that past efforts have been futile, or that small progress has been made. Rather, it seems to indicate either that no mind capable of fitting the great number of isolated bits of information together to form a comprehensive whole has yet appeared, or that some important factors have so far been overlooked entirely.

OBSERVATION AND EXPERIMENT

Of the infinite variety of phenomena which appeal to our senses, some, like those of sidereal astronomy, are subject, in the main, to observation only; while others, like those of terrestrial physics, chemistry and biology, are subject to both observation and experiment. All phenomena are more or less entangled. They point backward and forward in time; any one of them appears and disappears only in connection with others; and the record any one of them leaves is known only by its interaction with others. Out of this plexus of relations and interrelations it is the business of science to discover the conditions of occurrence and the laws of continuity. Happily for man, although the ultimate complexity of phenomena is everywhere very great, it is frequently possible to trace out these laws. But the results we reach are essentially first approximations, depending, in general, on the extent to which we may ignore other phenomena than those specially considered. In fact, a first step towards the solution of a problem in science consists in determining how much of the universe may be safely left out of account. Thus the method of approximating to a knowledge of the laws of nature is somewhat like the method of infinite series so much used by mathematicians in numerical calculations; and as it is a condition of success in the use of such series that they be convergent rather than divergent, so is it an essential of scientific sanity that the mind be restricted by observed facts rather than diverted by pleasing fancies.—*Professor R. S. Woodward, president of the American Association for the Advancement of Science, speaking before the New York Academy of Sciences, February 25, 1901.*

INHERITANCE OF MENTAL DEFECT

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MENTAL abnormalities in man are conveniently divided into two classes, defect and disorder. The distinction between lunacy and idiocy, though not entirely free from theoretical difficulty, is of great practical value and has been recognized since medieval times. An idiot is a person in whom mental powers are so impaired from birth or an early age that he never is able to take his place as a member of ordinary society. He is not capable of learning the necessary reaction patterns even to defend himself against common dangers. This situation is different entirely from that of a person who, for many years, participates in the normal life of the community but who breaks down in health and becomes incapacitated mentally. Notwithstanding, the mental level reached in severe chronic cases of mental disorder sometimes approximates to the level of idiocy.

The exact definition of what constitutes mental defect in the modern sense is made difficult by disagreements in terminology but, for general purposes, it is possible to speak of two main groups. The low grade, or severe cases, include those who are ineducable or only partially educable by special training and who are now known as idiots and imbeciles. Within these limits imbeciles are, by definition, more intelligent than idiots. The incidence of severe defect in the general population is estimated to be not less than one in four hundred. The high grade, or mild cases, are those who are educable, but lag behind the rest of the class at school. This group is considered to comprise about one per cent. of the general population and is made up of morons and "borderline" cases.

There are medical, sociological and biological reasons for the separation of severe and mild cases. The upper limit of the high-grade group merges into the general population; physically, most morons are not distinguishable from the normal, though some are short in stature and subnormal in head size. The majority of them live their whole lives without being noticed as unusual. Those who are poorly adjusted or who, in addition to defect, suffer from mental disorder generally become social failures in childhood, adolescence or later and require institutional training and care. From the biological point of view morons are quite well fitted to survive, provided their surroundings do not require the exercise of fine degrees of discrimination. They are able to produce families, or as some eugenists have expressed it, they can "proliferate"—people more generously endowed with ability and self-esteem are said to "breed." The low-grade cases are, on the other hand, almost completely infertile; at an early age it becomes obvious that they can not take part in the ordinary life of the community. They lack all initiative, and are very often physically malformed and unattractive to the casual observer. Their infertility is, for the most part, due to their incapacity to find a mate. While discussing this aspect of the subject it is well to point out that the fertility of high-grade defectives is often restricted probably for the same reasons —lack of initiative and unattractiveness. The solution found by some of them is to unite with one another, often without regard for the niceties of prevalent codes of morals. In this way clans have been founded in which the lack of intelligence coupled with fertility has attracted much

attention from sociologists. Enthusiasm for schemes directed towards eliminating such groups as these from the population is now not as great as it was a decade ago. The schemes for sterilizing a few selected cases or even all certified cases can not be expected to cause an appreciable reduction in the magnitude of the social problems due to the existence of these sub-cultural clans, at least within a century or two. People in several countries are now wondering whether before that time the defectives (and every one else) may not have been exterminated by bombs; alternatively, they hope that their defectives will survive so that as many of them as possible can be trained to supplement their man power. Nevertheless, it is a matter of great interest to medical science to know how mentally defective individuals of all kinds originate.

Adverse factors in the environment, which operate at any time after a child is born, are responsible for mental impairment in a certain number of cases. Some of these environmental factors are more often operative in the high-grade and others in the low-grade group. They must be appreciated before the hereditary factors can be intelligently discussed. If injury or disease affects the brain of an infant so that its subsequent development is impaired, defect may result but, in the opinion of most observers, no great proportion of the total number of cases of mental defect can be attributed to such accidents. A few cases of defect, usually severe, and associated with paralysis of one side or other of the body, are undoubtedly due to injury at birth. It is, however, incorrect to assume that injury at birth is a major factor in the production of mental deficiency. On the other hand, there is evidence that in the period before birth environment is by no means constant for every child, though detailed knowledge of the means whereby intra-uterine influences affect mental development is limited. In medicine it has been usual to speak of lues (syphilis) as capable of hereditary transmission but this, of course, is a misuse of terms. The infection can be transmitted from mother to child before the child's birth, and in this way damage may be caused to the brain of the child, sufficient to impair seriously its subsequent mental capacity. It has been estimated that from 1 to 5 per cent. of institutional cases of mental defect are, at least partly, due to congenital lues.

A somewhat more frequent group of cases also owes its origin in a large measure to prenatal environment but in quite a different way. These patients are called "mongols" because Langdon Down, who first drew attention to the group, thought that they resembled Chinese children. Actually such cases have been distinguished among Asiatic populations and in almost every country in the world. The appearance of slanting eyes, which these children sometimes show, is only one of a great number of characters which, when taken together, indicate a retardation of development, both of the brain and the rest of the body, at any early foetal stage. The most important factor in the origin of the "mongol" type of imbecile is associated with the age of the mother at the time of pregnancy. The affected child is often found to be the last born in a large family, but the cause is not dependent upon maternal exhaustion through too frequent child bearing—it depends upon maternal age alone. The risk of a woman's giving birth to a "mongol" child is approximately doubled every five years after she reaches the age of 25. Half the cases are born to mothers who are more than 37 years of age. The father's age does not seem to matter at all. There are also other abnormalities of development of the nervous system in which the cause is associated with the

age of the mother though in a lesser degree than is the case in mongolism. In some of these conditions the chance of the first-born child's being abnormal is slightly greater than the chance of abnormality in the children born afterwards to the same parents. Recently the investigations of Murphy have also shown that therapeutic doses of x-rays given to a mother during pregnancy increase the risk of her giving birth to a malformed child.

The external influences which are significant in the severely affected group belong to the field of medicine. The influences of social environment, however, are significant in relation to the mild cases. Intelligence probably can not be altered by education, but certifiability and necessity for institutionalization depend very much upon training. The high-grade cases—the morons—are abnormal chiefly because they are unable to be good citizens. Those of the worst characters and habits are the most likely to be certified. Scarcely one tenth of the number of morons who actually exist in the population are to be found in institutions, even in those communities where mental health is most assiduously looked after. Intelligence, like stature, is graded and there is not a natural cleft between the normal intelligent person and the moron; consequently, the line between the two has to be drawn arbitrarily. Its position depends upon a delicate balance between individual ability and the reaction of the individual to the demands of the social environment in which he finds himself.

The true hereditary factors which cause mental defect are determined at conception, and their effects become manifest at any time during the early life of the individual. The family history in cases of severe defect usually differs in a number of ways from the family history in the mild cases because the hereditary mechanisms which act in the two types of cases are probably different. It will be convenient first to discuss the low-grade cases. Here the parents are, as a rule, normal physically and mentally; so, also, are the majority of the patients' brothers and sisters. Occasionally two or more idiots or imbeciles are born to normal parents, but this is exceptional. If one child affected in this way has been born, and if the parents are both normal, the chance that another child will be affected is less than 3 per cent.[1] This prognostication presupposes that the exact nature of this defect is unknown, for there are a number of specific diseases which cause low-grade defect and which behave as Mendelian recessive characters. If a recessive condition is diagnosed, the chance, that brothers and sisters of the affected child will suffer from the same condition, is 25 per cent. in the usual case, where the parents are both unaffected.

Some of the recessive diseases which cause imbecility or idiocy are of great medical and biological interest to those people who are lucky enough not to be affected themselves. Two forms are known of a progressive, degenerative condition which causes children, though at birth they appear healthy, to become blind and paralyzed idiots either in infancy or during school age. These illnesses are, fortunately, extremely uncommon. The infantile form is practically only found in Jewish populations. Naturally, no affected person ever has children of his own. The family history often shows the characteristic picture of a rare recessive disease, *i.e.*, parents normal, and related to one another by consanguinity, with one or more affected children and also some perfectly normal children. Another very interesting recessive disease, which causes gross mental retardation, but which is not progressive, was identified in Norway a few

[1] *Eugenics Review*, p. 85, 1939.

years ago by a biochemist, Fölling. He found that a substance, phenylpyruvic acid, was always present in the urines of certain imbeciles; in the normal person this substance is not excreted at all, possibly because it is utilized in the functioning of the brain. The disease seems to be more widely spread in Norway than in some other countries, though cases have been described in England, Scotland and France. In the United States many cases have been found, but only a small number of them have Norwegian ancestry. Other important recessively determined types of mental defect are associated with symmetrical paralysis of both sides of the body from birth or any early age. These cases of "cerebral diplegia," or Little's disease, are sometimes ascribed erroneously to birth injury. Normally the condition is not progressive. There is a variety of types, and it is certain that some of them are recessive characters. There are also many more conditions inherited in the same way and often associated with severe mental impairment. Among these are some types of cretinism, deafmutism, congenital eye defects and extreme underdevelopment of the brain (microcephaly). Cases of severe mental defect, which are genetic in origin and yet are not due to recessive factors, form another group. Their occurrence is, for the most part, sporadic; that is to say, they occur unexpectedly in normal families. One curious disease, in which the brain is malformed in a manner which, according to the pathologists, resembles potato roots (tuberose sclerosis) and in which tumors develop on the skin and in other parts of the body, often causes severe mental impairment and epilepsy. A fairly large proportion of these cases is sporadic. In some instances, however, usually when the patient is not severely affected, another member of the family, perhaps a parent, suffers from the same condition. The explanation is probably that tuberose sclerosis is due to a single dominant gene mutation. The assortment of abnormal characters produced by a fresh mutation of this gene gives rise to a condition so serious that an affected person is unlikely to have any children and, thus, does not usually transmit the abnormalities to the next generation. From a knowledge of the frequency of occurrence of cases of defects due to fresh mutation, the mutation rates of certain genes in man have been estimated. If the length of life of man, as compared with that of the fly, is taken into consideration, the mutation rate is found to be of the same order of magnitude in both species.[2]

An important group of low-grade cases, which already has been referred to, includes the mongolian imbeciles and a large variety of severe types of congenital malformation. The significance of maternal age in relation to these conditions, has already been mentioned; probably this association denotes a contributory cause which enables an underlying disposition to become manifest. The nature of the underlying disposition can, at present, only be surmised. The experimental work of Snell and others, on malformations of the nervous system in mice, suggests that in those animals derangement of the normal chromosome pattern may be a cause of such defects. The same kinds of peculiarities quite conceivably can occur in chromosomes of man. They might be expected to cause severe abnormalities with familial incidence so slight that the majority of cases would appear sporadically.

In order to complete the description of the genetical factors underlying severe mental defect, attention should be drawn to a few diseases which are sometimes associated with it and which are due to sex-linked or partially sex-linked genes. These include some of the my-

[2] *Nature*, 135: 907, 1935.

opathies (progressive muscular degeneration) and some eye diseases. On the whole, sex-linked inheritance seems to play a comparatively small part in determining intellectual subnormality. Sufficient has been said to show that the hereditary background of the low-grade cases is complex and varied. Recessive factors play an important part, but the hypothesis, favored by Goddard in his pioneer work on this subject, that all heritable mental defect is a single recessive trait, is untenable.

When the family histories are investigated in cases of mild defect—the morons, the simpletons, the weak-minded or whatever designation is preferred—a different picture is obtained. An appreciable number of the parents are found to be of mental caliber no greater than that of the offspring studied. The proportion of defective parents is estimated by various observers to be from 15 to 50 per cent., according to the position of the arbitrary standard set for defining what constitutes the lower limit of normal intelligence. Since the major part of the group of mild cases is only arbitrarily distinguished from the normal, the laws which govern the inheritance of intelligence in the normal group are likely also to hold for the subnormal or "subcultural" group (as Lewis termed it). According to what is known at present, intelligence—in so far as it is an innate quality—is determined by a large number of hereditary factors, some dominant, some recessive and some cumulative in action. The general rule which covers multifactorial inheritance of this kind is that the average intensity of the quality so determined will be the same in the children as it is in the parents. That is to say, the combined intelligence rating of the parents sets the standard rating for their children, some of whom, however, will possess ability above and some below this level. If, in addition to subcultural mentality a particular patient should have the misfortune to suffer from a mental disorder, such as epilepsy or schizophrenia, the genetic causation of the disorder must be analyzed separately to give an accurate picture of the hereditary background of the case.

In conclusion, it is of some interest to speculate upon the possible value and limitations of eugenic proposals for eliminating mental defect by selective sterilization. Since the severe cases are mostly infertile the eugenic attack must be made on potential parents of imbeciles and idiots. This will involve the sterilization of the carriers of defects, who will themselves be healthy in nearly every instance. At present these normal carriers, though they are known to be much more frequent in the general population than are imbeciles and idiots, can not be identified with certainty until they are already the parents of at least one abnormal child. The attempt to eliminate recessive or sporadic conditions from the population by eugenic sterilization will be a thankless task to say the least. Natural selection has failed to do this in thousands of years.

The attempt to eliminate mild cases by eugenic measures encounters other difficulties. It would be theoretically possible to diminish the incidence of high-grade defect in a sensible degree by sterilizing every person whose mental ability fell short of some specified margin. The problem of how best to define this margin efficiently has, however, not been solved. If the margin is low, the results of the efforts are ineffective. If, on the other hand, the margin is set high enough to be really effective, it would mean that about a tenth of the population might have to be prevented from having children. At the present time, when numerically large populations are considered to be desirable, no such proposals as these would meet with general

approval. Some authorities have given publicity to the belief that, in most civilized countries, the average degree of intelligence is declining because the morons have the highest reproduction rate in the community. If this is true, to sterilize the most fertile group would be suicidal. More probably it is not true. The highest fertility in the community perhaps does not rest with the most highly cultured groups, but it is probably associated with a degree of intelligence which, if not one hundred per cent., is only just below the average level —well within the range of what is considered to be normal ability. It would indeed be rash, in this fluctuating world, to lay down hard-and-fast principles about what human beings were most suitable to survive in the long run. A high general level of intellectual ability is probably necessary for the satisfactory development of civilization, but the most biologically efficient human beings can not be classified on the basis of intelligence alone.

DISEASE DAMAGE IN GRAINS

By Dr. NEIL E. STEVENS

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In a nation which has already become accustomed to some form of crop acreage control and in which experiments in crop insurance are being conducted, information regarding crop losses due to disease is of importance to thoughtful citizens. It is the purpose of this article to present the available evidence on this subject as it relates to our basic food crops, the grains.

Two sets of disease loss estimates derived from quite different sources have been published by the United States Department of Agriculture. For the years 1909 to 1925, inclusive, the percentage of damage caused in various crops was compiled from estimates sent in by thousands of crop reporters in all parts of the United States. The estimated annual reduction for these years, together with the average for the years 1916–1925, was published on pages 321–322 of Volume 3, Supplement Number 10, "Crops and Markets." Apparently no figures of this type were published after 1925. The averages for the decade 1916–1925, which are slightly higher than for the earlier years, but fall in the same order, are in percentage: wheat, 5.2; oats, 2.8; barley, 2.7; corn, 0.4. Rye is not mentioned.

The order in which the various grains fall in this list seems to agree with the general impression among informed agronomists. Wallace and Bressman[1] say (page 139) "Corn is freer from disease damage than most other crops." Moreover, in a series of articles discussing progress and possibilities in plant and animal breeding, prepared by specialists of experience and high standing in their respective fields and published in the United States Department of Agriculture Yearbooks for 1936 and 1937, relatively much more space was given to discussing disease resistance in wheat, oats and barley than in corn. The relative amounts expressed as percentage of total space which was given to this phase were: wheat, 11.5; oats, 10.5; barley, 7.0; corn, 1.9.

Beginning in 1917 and continuing to the present time, the Plant Disease Survey has assembled and published esti-

[1] H. A. Wallace and E. N. Bressman, "Corn and Corn Growing," fourth edition. New York. 1937.

mates of crop losses sent in by collaborators, professional pathologists, in the various states. These figures are estimates in the true sense of the word, and no pretense is made that they represent a high degree of numerical accuracy. They are, however, the best obtainable and certainly should be considered in any attempt to evaluate the losses caused by plant disease in the United States. These estimates of losses due to disease in the four small grains for the period 1917–1937 are given in Figs. 1 and 2. Certain correlations between these figures and those derived from the estimates of the crop reporters are at once apparent. Throughout the period, the losses in rye, not mentioned at all in the other list, are smaller and fluctuate less than those of the other grains. Losses in wheat on the other hand are estimated as being higher and fluctuating more than those of any other small grain. The most striking contrast is, of course, between wheat and rye.

As regards disease losses in corn, the agreement between the estimates compiled by the Plant Disease Survey and the figures obtained by the other method is less evident. The disease estimates for the two most important grain crops, wheat and corn, may be directly compared in Fig. 3.

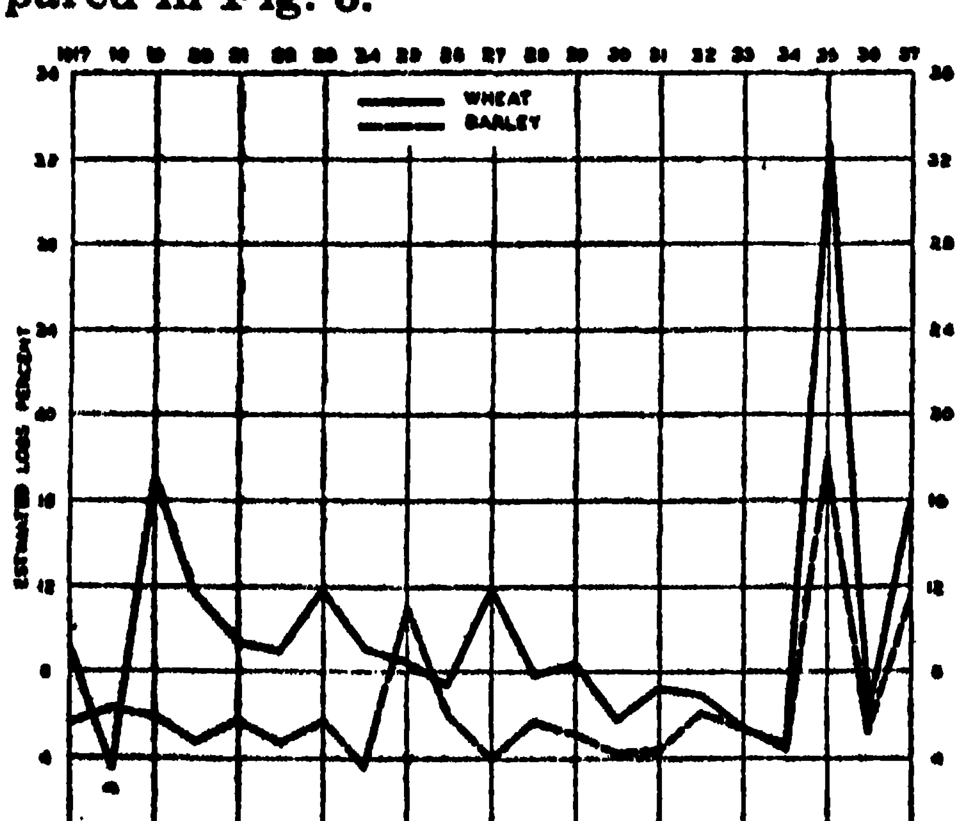

FIG. 1. ESTIMATED LOSSES FROM ALL DISEASES OF WHEAT AND BARLEY IN THE UNITED STATES (REPORTING AREA) 1917–1937.

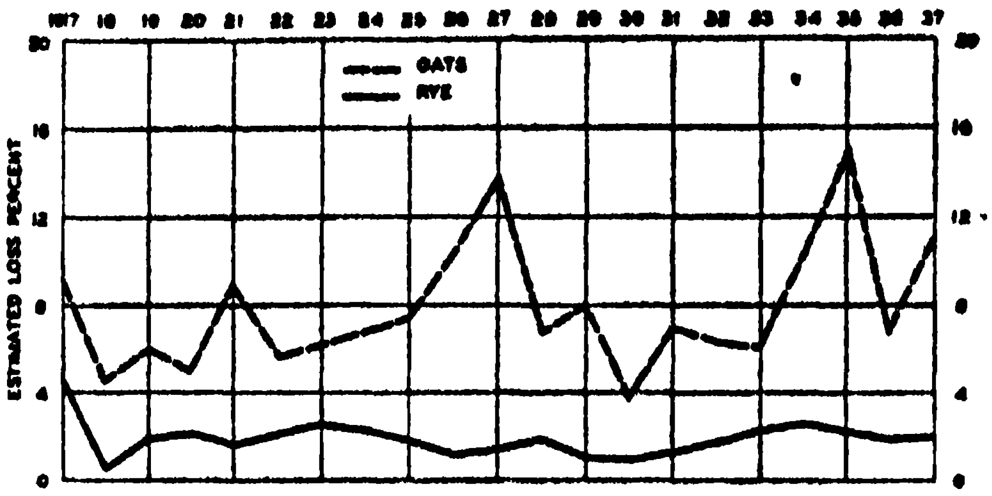

FIG. 2. ESTIMATED LOSSES FROM ALL DISEASES OF OATS AND RYE IN THE UNITED STATES (REPORTING AREA) 1917–1937.

In the loss estimate figures derived from reports of the crop reporters, corn appears at the bottom (0.4 per cent.), wheat at the top (5.2 per cent.), whereas in the figures compiled from reports of the collaborators of the Plant Disease Survey, the *average* losses in wheat and corn for the twenty-year period are approximately the same: 9.86 for wheat and 9.74 for corn. A possible explanation of the difference may be found in the different points of view from which the estimates were made. It seems entirely reasonable that considerations of economic importance of disease, rather than of total losses, greatly influenced the estimates of the crop reporters, many of whom were growers, or were commercially interested in crop production.

Among the factors which go to determine the economic importance of a disease, total average loss is only one item, and perhaps far from the most important item. In any list of factors to be considered in determining the economic importance of a disease, the extent to which the losses it causes fluctuate from year to year must occupy a place. Under present economic conditions, at least, fluctuations in losses are no doubt more important than total losses. Equally certain is the fact that large fluctuations must be very much more important than small ones. The extreme case is of a fluctuation so great as to produce actual famine conditions which would be *infinitely* more important than smaller ones. The difference between wheat and corn

in this respect is clearly shown in Table 1, in which, indeed, the relative positions of all the grains show a striking correlation with their positions in the list derived from the estimates of the crop reporters.

TABLE 1

FLUCTUATIONS IN CROP LOSS ESTIMATES COMPILED BY PLANT DISEASE SURVEY. NUMBER OF YEARS 1917–1937 SHOWING THE INDICATED DIFFERENCES FROM THE PRECEDING YEAR

	2 Per Cent. or Less	2–4 Per Cent.	4–8 Per Cent.	8–16 Per Cent.	Over 16 Per Cent.
Wheat ..	8	4	4	2	2
Barley ..	14	1	3	2	.
Oats ...	8	5	6	1	.
Corn ...	10	5	5	.	.
Rye	19	1	.	.	.

It would appear from these figures that the stability of yield of corn has been much less affected by disease than has that of wheat. The contrast between our two great cereal crops as regards *dependability* is recognized in the Agricultural Adjustment Act of 1938.

The corn acreage allotment was calculated to produce, including the entire crop and carry-over, a total supply equal to 110 per cent. of a normal year's domestic consumption and exports. The wheat acreage allotment was calculated to produce with the carry-over not less than 130 per cent. of a year's normal domestic consumption and export requirement.

Likewise, marketing quotas for the commercial corn-producing area were to be announced for the following year, subject to a referendum, if the total supply was estimated at more than 10 per cent. above the normal supply. Marketing quotas for wheat, on the other hand, were to be proclaimed only if this supply should exceed by as much as 35 per cent.

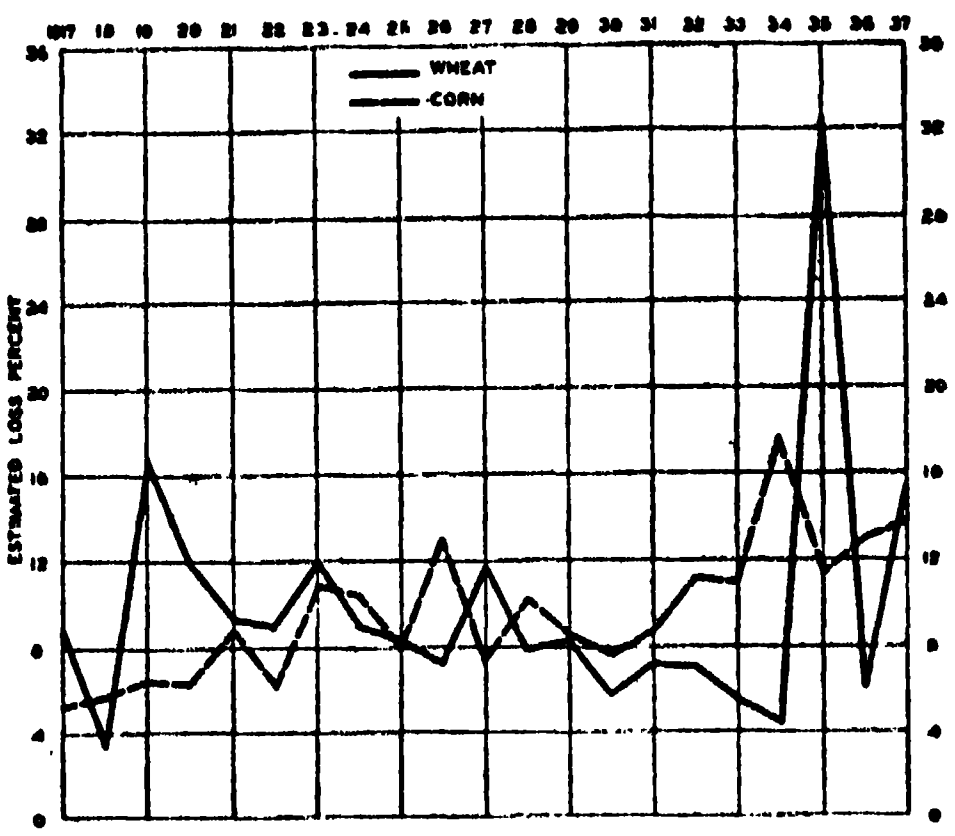

FIG. 3. ESTIMATED LOSSES FROM ALL DISEASES OF WHEAT AND CORN IN THE UNITED STATES (REPORTING AREA) 1917–1937.

a normal year's domestic consumption and export requirements.

Of course, factors other than fluctuations in size of crop enter into these figures. Also, factors other than disease help cause these wide fluctuations, but as stated on page 115 of the report on agricultural adjustment for 1937–38, the wheat farmer faces two chronic dangers —the risk of crop failure and the danger of tremendous surplus. If crop failures due to rust epidemics could be eliminated, it would be easier to guard against the surpluses.

Secretary Wallace has said, "Fluctuations in yields cause as much embarrassment as unbalanced acreage."[2] An important part of the work of American plant pathologists would seem to be to reduce the *fluctuations* in plant diseases. Most attention may well be given then to those food crops in which the losses from disease show the greatest fluctuations. A survey[3] of the literature of plant diseases during the past half century or more indicates that this has been the case.

[2] *New Republic*, December 2, 1936.

[3] Neil E. Stevens, SCIENCE, 89: 339–340. 1939.

THE HIGHER EDUCATION: CONTROLLED OR UNCONTROLLED?

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In the Pennsylvania Study[1] it is reported that students showed measured gains as great or greater in some subject-matter fields not part of their curricula as they showed in the subject-matters upon which they were ostensibly concentrating. Whence come such gains? Are the courses in professionalized subject-matters so enriched in the teaching process that they yield striking gains in fields only remotely related to them?

When the students in the last two years of an engineering curriculum are reported as making gains in fine arts, in foreign literature and in English literature as extensive as the gains shown in science and mathematics, what are we to infer? Does the engineering curriculum in its later years operate in a cultural environment of singular richness? Do the instructors go far afield in providing a background of unexpected breadth? Or are teachers taking credit—and blame—for phenomena over which they have little or no control?

Without in the least disparaging the cultural environment of the engineering school or the quality of engineering instruction, may we not legitimately suspect that the phenomena are quite beyond the control of the school? Perhaps we may even suggest the hypothesis that the phenomena reported are beyond the control of the students themselves!

We tend to accept without question the inference that measured gains shown on successive applications of comparable subject-matter examinations are the result of teaching and learning efforts. The writers of the Pennsylvania report and their commentators have accepted this inference. They have also expressed the corollary inference that failure to show gains, individual and institutional, implies lack of effort or forthright poor teaching.

In the light of our own research results we are impelled to the view that the foregoing are not sound inferences. When we tried to interpret our results in terms of these inferences we found ourselves in a dilemma. The statistically derived facts did not fit these conventional explanations. Escape from the dilemma required a new hypothesis for explanation.

Our attention was first attracted to the situation when we considered the disparate results from attempts to distribute grades to 259 students in a first-year course in biology. The Biology Department had assigned its grades solely on the basis of total scores obtained on five long and well-constructed objective examinations. Comparable forms of the Cooperative Test Service biology tests had been given at the beginning and again at the end of the course. This test at the end of the course presumably reflected the *level* attained at that time in the subject-matter field—at least, that is the implication from the Pennsylvania study. Similarly, the difference in standard scores for each student on the two tests represented his gain achieved as the result of his instruction.

When we made a distribution of grades

[1] Learned and Wood, "The Student and His Knowledge," Bulletin Number Twenty-Nine, The Carnegie Foundation for the Advancement of Teaching, 1938, pp. 28 ff.

for these students, using level on the second standard test as a basis, and compared these grades with those awarded by the department, we found general agreement between the results. In a few instances students received C by one method as against F by the other, A by one and C by the other, or D by one and A by the other.

When we made a similar distribution using gains as the basis, we encountered startling disagreements. Students who deserved A's on this basis had received F's and D's from the department; others who would receive F's and D's by this method had received A's and B's from the department. These disagreements were so great and so numerous that we made a correlation study of the whole set of interrelationships among test scores, gains, grades and intelligence test results.

The results were unexpected and perplexing. In the sub-group numbering 217 who had taken a one-year course in biology in high school gains correlated only .04 with grades; while for the sub-group of 42 with no previous study of biology this figure was .19.

Still more disturbing were the relations between intelligence and gains. Here the figure for the larger group was $-.14$ as against $-.29$ for the smaller group. There must have been errors in the calculations: they were made again, independently, with the same results. Clearly, from these figures, the measured gains were significantly related neither to grades as awarded nor to intelligence as measured.

Why should we expect any other result? We have always awarded grades with the tacit assumption that they reflected achievement, attainment, growth, mastery or gain—partially if not wholly. It is apparent that this assumption is quite unjustified in the situation studied.

From the definitions of intelligence, implying as they do a mental alertness, a quickness to grasp, a readiness to learn, to meet new situations, to grow, as well as from the nature of the instruments used to measure this ability, it is a fair inference that higher intelligence implies an associated ability to make greater subject-matter gains. Not only is this not a correct inference, in the light of these results, but something slightly the opposite seems to be implied.

This must be a chance result, in spite of the odds against it, we thought. The American Council Psychological Examination is of known high reliability; The Cooperative Test Service standardized tests are known to be of high reliability; and the five objective examinations upon which grades were based were also found, upon subsequent analysis, to be highly reliable. Careful check of the figures disclosed no errors in the calculations. Perhaps the situation was peculiar to this course alone.

The following year the study was repeated, this time in a course in modern European history. The content was different, the methods of instruction were different and the basis for awarding grades was different. But the results were practically the same.

In two groups of 126 each, taught by different instructors, gains correlated .02 and .12, respectively, with grades; and $-.19$ and $-.14$, respectively with intelligence. The probability of such results by chance alone is infinitely small. We are confronted with a major dilemma.

In the meantime we had extended the biology study over two semesters with 88 students from the original group. For these students their first-semester gains correlated .23 with grades and .02 with intelligence; second-semester gains correlated .20 with grades and $-.01$ with intelligence. In the light of our previous beliefs this should not happen. But it has happened.

We must formulate an explanation that will fit these results. If the gains

are shown to be relatively independent of both scholarship in the usual sense, as well as independent of intelligence as usually measured, to what are they significantly related? We can not answer, because we have no data.

We may suspect that these measured gains reflect some underlying or innate growth factor, that they result from some obscure mental maturation process that continues long after the usual measured intelligence growth has attained its maximum. This seems to be a plausible hypothesis, but only a hypothesis.

We may suspect that the underlying function may take the form of known growth curves. We should then expect to find differences in the rates of acceleration of such curves for different individuals. We actually find a normal distribution of gains, indicative of such differences in acceleration.

We may further suspect—and this may be most important—that such curves will reach their maxima at different ages for different individuals, marking the points at which such growth stops. The failure of many students to show any gain, noted in the Pennsylvania Study as well as in our own, supports such an inference. Obviously, a student who has attained his maximum can not show any further gains any more than can the high-jumper who has attained his physiological limit show any further gains in the height of his jump.

To what traits of human behavior is this apparently dynamic function probably most closely related? We have long been puzzled by the continued personal growth of some students whose college records were poor and whose intelligence test scores were low. Could it be possible that their later attainments were due to this underlying function that had not attained its maximum?

We are similarly often disappointed by the failure of many brilliant students of high measured intelligence to achieve distinction after their college days. Could they have reached their maximum in this function during or soon after the completion of their college courses, resulting in an arrest of further growth? This may be a tenable hypothesis.

The function seems to be dynamic in character and as such some sort of "potentiality for growth," but it may be better to name it only with a symbol and restrict its meaning by a simple definition: *Iota Function—the function responsible for successive gains on comparable forms of standardized subject-matter examinations.* This will help to avoid the difficulties inherent in all descriptive labels.

The Iota Function seems to be firmly established as a mathematically verifiable phenomenon if not as a fact of sense-perception. What is the next step? Clearly we must measure its effects and record them over a sufficient period of time to permit us to learn more of its nature. We may never know any more about the function itself than we now know about gravitation, but we can learn much about its effects.

In the light of the foregoing hypothesis, how may we interpret the peculiar phenomena of the Pennsylvania Study? If measured gains are due to some innate growth factor, a factor apparently not significantly related either to scholarship or to intelligence as these are usually measured, the individuals and the institutions they attend are not to be praised or blamed for such gains. Neither can individual instructors be compared with each other in teaching efficiency on the basis of the gains shown by their students.

It is also apparently quite possible that the sizes of the classes taught may not affect this phenomenon. This possibility must be examined with care, since it may have an important bearing upon the economic aspects of education quite apart from the problem of administra-

tive control. The traditional arguments for the small, personalized classes and the small colleges themselves may be questioned.

How, then, are we to explain the differences in average gains reported among the colleges in Pennsylvania? The annual reports of the average standings on the American Council Psychological Examinations have shown certain colleges at the top, others at the middle, and still others at the bottom of the list, year after year. These relative positions are maintained regardless of the fact that many of the institutions do not use the test scores as a criterion for the selection of students. The same sort of selective factor that is responsible for this intelligence phenomenon is probably responsible for the gains phenomenon. In both instances this factor would seem to be operating largely without the volition of the admissions personnel.

If the differences reported are due to selection, failure to show gains can only be corrected by amendment of the selection procedures, not by changes in instruction processes. The problem becomes one of identifying prior to admission, the students having the greater promise of such subject-matter gains. This in turn implies suitable records of similar growth during the high school and possibly during the elementary school years.

If curves of subject-matter gains are deducible from previous records—records of comparable scores on comparable examinations—the task is comparatively simple. Sufficient data should make it easy to project the appropriate curves into and perhaps through the college years and afford a basis for the prediction of gains.

The lack of appropriate measurements during the pre-college years is the main obstacle to an immediate application of such selection methods. Nevertheless, if this Iota Function is as important as it seems to be, and its measured gains are to be made a criterion of academic success, the necessary data must be accumulated and made available to the colleges.

There are other implications of the Iota Function phenomena which extend beyond the college years. The hypothesis may be offered that students who show positive acceleration of their gains in their fields of major effort are the best candidates for the graduate and professional schools. Such students would seem to offer the promise of greatest personal accomplishments and most extensive contributions to their chosen professions. This hypothesis, too, requires experimental verification.

It is apparent that many of our traditional beliefs and some of our educational practices will have to be reexamined anew in the light of the Iota phenomenon. Perhaps we are wasting both time and money in misguided attempts at instruction. Perhaps we are dispensing both praise and blame where they are undeserved. Perhaps we are dealing with a fact of human nature which we can only control through human adaptation, as we now control the weather.

BOOKS ON SCIENCE FOR LAYMEN

MENTAL SICKNESS[1]

THE author of Ecclesiastes lived before the days of "popular psychology," else he might not have been so prone to understatement when he wrote, "of making many books there is no end"! The veritable flood of pulp magazines and books devoted to the alleged purpose of teaching the reader to "control his mind" and avoid mental disorder is an eloquent testimonial to a need for guidance and reassurance on the part of many individuals. This is not to say that good advice for the laity is not to be found in some books and in some reputable journals; even though self-prescription is usually dangerous, there are excellent volumes written primarily for non-medical readers and dealing with the nature of mental troubles and their prevention. The very avidity of the public, however, should cause the prospective author to be very sure of his facts and of his way of expressing them. Careless expression and oversimplification of statement may sometimes have untoward effects on the introspective reader.

The present volume is evidently meant for popular consumption. It is a bulky volume, consisting of 22 chapters, breezily written and loosely put together. Many brief case histories are given, interspersed with comments and rather sweeping statements, sometimes of highly doubtful scientific accuracy.

Alcoholism, one of the important examples of poor mental hygiene, is dismissed with a chapter of 2½ pages, while two chapters (31 pages) are devoted to schizophrenia and "how the schizophrenic speaks"—an important subject to the psychiatrist, but hardly so comprehensible to the lay reader as might be a discussion of the meaning of alcoholism. We are told that excessive smoking and excessive use of coffee are "a cause of restlessness" (p. 18) (probably they are more often the result!), and that "the importance of chronic constipation . . . as a cause or contributory cause of the most destructive diseases, mainly physical, but also mental, has not been emphasized strongly enough" (p. 366). Again, we learn that poverty is one of the causes of mental deficiency (p. 87), and that retarded children should never belong in the ungraded classes (p. 89)! A final scientific gem, following the statement that most homosexuality is acquired, runs thus: "Homosexualism is also spread in the so-called underworld, that is among prostitutes and their parasites, among people with low-grade mentalities and among the decaying European feudal nobility and money aristocracy in Europe and in America" (p. 123).

The motives of the author in attempting to present some understanding of mental processes are undoubtedly excellent. Unfortunately, the volume can hardly be termed sound or scientific, however readable it may be.

WINFRED OVERHOLSER, M.D.

[1] *Your Mental Health.* B. Liber, M.D. xvi + 408 pp. 1940. Melior Books.

UNITS OF LIFE[1]

THIS book presents a clear account of modern views concerning the nature of living things. Professor Gerard has succeeded in describing all the important vital functions in a readable, forceful manner which requires no specialized biological training on the part of the reader. The style is not dogmatic; many biological problems are introduced as essentially questions awaiting a final answer.

[1] *Unresting Cells.* R. W. Gerard. Illustrated. xiv + 439 pp. $3.00. 1940. Harper and Brothers.

The most attractive features of the volume are the original illustrations and diagrams—the skilful work of Elisabeth Buchsbaum. The figures take the form of cartoon sketches in which various forces at work in living systems are represented as active manikins and demons engaged in many amusing activities, such as carrying buckets of water, opening trap doors, selecting food in cafeterias and even marching up church aisles to the altar. In every case some important physiological fact is conveyed to the reader without distortion or exaggeration. It is amazing to find very complex physiological events so simply and clearly presented at a glance.

The plan of the book is logically arranged and gives first a description of the physical and chemical basis of living matter. Structural formulae are greatly clarified by clever diagrams. Then follow descriptions of types of living cells. The later chapters deal with growth, reproduction and heredity. The book closes with emphasis on the organism as a whole. The final focus of attention on the living being as an integrated unit is essential for a well-balanced presentation of physiology.

This reviewer believes that the book gives too much importance to the somewhat old-fashioned concept of "the cell." Thus connective and cardiac tissue have no "cellular" organisation. Moreover, little is gained by including a spherical egg cell and a yard-long nerve fiber under the same category. Professor Gerard, of course, points out these difficulties.

The book would be improved by a chapter or section dealing with physical models representing physiological function. A drop of mercury will pulsate like a heart if touched with a needle. All the electrical properties of living systems can be duplicated by physical models consisting of layers of oil in simple solutions that Dr. Beutner has described. The addition of a bibliography, too, especially of works of a general nature, would be of great value to the many readers who will be inspired to follow the subject of physiology in greater detail.

The book is by far the clearest and most comprehensive presentation of modern general physiology for the layman, and closes with the encouraging statement that "The huge weight of biological experience must give us strong hope that civilization is not doomed to destruction."

T. Cunliffe Barnes

IS INFLATION AROUND THE CORNER?[1]

Every great war in modern times has been accompanied by a large increase in commodity prices, followed by an equally marked decline. Inflation has also followed excessive national debt, as in France about 1790 and in Germany after the World War I. The United States is virtually involved in war, and it is adding billions and billions of dollars to an already unparalleled debt. Consequently, millions of people are anxiously inquiring whether inflation now menaces the purchasing power of their accumulations in life insurance policies and other dollar securities, including the social security annuities provided for by the government.

Dr. Hardy does not categorically answer these inquiries on the basis of the many precedents history offers nor by arguments based on classical economic theories. Instead, he starts with the fact that the United States is committed to a prodigious war mobilization of men, materials and machines, and he inquires how this great effort can be made with the minimum of disturbance to the economy of the country and consequently

[1] *Wartime Control of Prices.* Charles O. Hardy. x + 216 pp. $2.50. 1940. The Brookings Institution.

with the maximum of efficiency and over-all good. Perhaps this approach was stimulated by the fact that the investigation was made at the request of the War Department. In any case, it is excellent.

The book opens with an introductory chapter consisting of a clear and very readable statement of the systematic manner in which the question is analyzed and answered. No description can give as clear an idea of the approach as a mere list of the points raised and discussed. Part I consists of an analysis of the factors involved in the determination of the prices of commodities in times of war; and Part II consists of a review and appraisal of the price advances and the controls of them that were used or attempted during World War I, with constant references to the considerations presented in Part I.

The questions considered in the Introduction are indicative of the analyses in Parts I and II. Among these subjects are: "What are the sinews of war? What part does money play in the mobilization of a nation's resources for war? What is the significance of price in a war economy? Large government purchases on a competitive basis. Speculation in commodities. Uncoordinated government buying. Competitive bidding for labor. The expansion of bank credit. Does price inflation tend to expedite or to retard effective mobilization for war? How does price inflation affect the distribution of the war burden among the various groups in society? Does price inflation serve to increase or decrease the cost of a war to the nation? What is the economic aftermath of war-time price inflation? Does government borrowing through bank credit expansion shift the burden of a war to future generations? Is it possible to finance a war entirely from taxes and from loans paid out of current income?"

There should be no surprise that these questions relate so explicitly to the war, for it is the primary occasion for the whole question of possible inflation and its effects. Any controls or attempted controls that may be devised must be subservient to the primary purpose of rearmament.

The conclusion reached by the author is "that a serious inflation of prices in time of war can be prevented. The explanations of the great price inflations in past wars is to be found in an unsound fiscal policy; in part in the unrestrained use of the competitive price mechanism as a means of bringing about war mobilization, and in part in the adoption of faulty principles of price control when finally the necessity for control was discovered."

In view of the disastrous consequences that would result from inflation, we may fervently hope that those who perhaps can prevent it will have the wisdom, the legal power and the administrative ability to act effectively when action is necessary. And if all these conditions are met we shall have lost, at least for a time and perhaps permanently, some of the liberties we have traditionally cherished.

F. R. MOULTON

WAR CORRESPONDENCE FROM THE CANCER FRONT[1]

EXCITING as a report of battle and yet as charmingly human as an intimate conversation is the little book just off the press in which Dr. Sokoloff tells the story of the fight against cancer. With rare skill the author has beautifully succeeded in reporting briefly some of the outstanding achievements in cancer research and in defining the complexities of the problem. While never denying the tragedy of neglected cancer, the book is filled with the sunshine of hope; hope that the advance of knowledge through tireless research and that the dissipation

[1] *Unconquered Enemy.* Boris Sokoloff. x + 198 pp. $1.75. 1940. The Greystone Press.

of knowledge through persistent education will prolong many lives and prevent much suffering now unnecessary. Avoiding sentimentality and emotional appeal through sensationalism, the author has been able, nevertheless, to infuse a living enthusiasm and interest by his excellent thumbnail sketches of scientists at work.

The style is exceptionally appropriate to presentation of scientific data and concepts to laymen. One reads quickly, with pleasure and interest. With a fine comprehension of values Sokoloff paints the grandeur of research. The scientific facts are sound, and his critical appraisals of present investigations impartial. Naturally, much factual and theorectical knowledge of neoplasmata is omitted for the sake of brevity and simplicity. The book is enthusiastically recommended to those whose interest in cancer is neither technical nor very profound.

EDWARD J. STIEGLITZ

CONTROL OF DEVELOPMENT, DIFFERENTIATION AND GROWTH[1]

IF, at an early embryonic stage in development, especially of the amphibian egg, parts of the outer cell membranes from which the neural groove would develop are transplanted to another part of the embryo, there will be formed in the new place a neural tube, and also appropriate adjacent structures, such as would otherwise never have developed in that place. To account for this phenomenon the hypothetical substance called by Spemann "the organiser" has been invoked. The author of the present book, who is a nomenclatorophile, likes to call this, or the substance it produces, the "evocator." The gene is in some way responsible for the development of organs in their normal place in the normal embryo. The author, an experienced embryologist, says of his book: "I have devoted some space to point out the similarities between the concepts derived from the consideration of the organiser and those which arise in connection with the developmental effects of genes."

Of his book the early chapters are devoted to this evocator and the search for its chemical nature. The search for the substance that organizes development, or calls forth a new part, has so far not been crowned with much success. The author, working with Joseph Needham, also of Cambridge, England, has finally reached the conclusion that the substance belongs to the group of sterols. But the history of their search reminds one of Loeb's search for the substance that the sperm brings into the egg to start its development. After announcing the discovery of several, one after the other, Loeb concluded that a variety of agents might start development of the parthenogenetic egg when the egg was all ready for fertilization. In similar fashion some experiments report that mechanical irritants, such as silica or certain substances that injure the cell, may "evocate." Now the conclusion seems to be that the evocator evocates the evocatable. This is not a great advance over Aristotle's epitome of the ontogenetic process: Part acts on part. Still, concentration on the study of the organizer and the conditions under which it is active is opening up a new field of research which the author describes in this volume in some detail.

In his discussion of genic action the author gets farther. His chapter on the temporal course of gene reactions is good, but he does not perhaps sufficiently emphasize the fact that the time of first appearance of a new organ is not necessarily the time at which the anlage of

[1] *Organisers and Genes.* C. H. Waddington. 160 pp. $3.00. 1940. Cambridge University Press.

that organ has been formed. Even the anlage has precursors that might in some cases be traced back to the fertilized egg.

A chapter is devoted to "individuation," which is the author's preferred name to differentiation. As he points out, the process of individuation is different from the process of evocation. The evocator changes from time to time, or the substrate upon which it acts does, so that in the course of development new and different structures are added to the earlier and less differentiated ones.

The author's synthesis of the action of organizers and genes is not quite as complete as might have been hoped for. Both are responsible for development at different stages, but there is no good evidence that they work in the same way.

The book is a useful and successful attempt to bring together the observed facts of the action of the hypothetical organizer and many of the effects of the action of the gene. One is grateful to the author for directing attention to the physiological factors which control development, differentiation and growth. The bibliography is full and up to date. The book will be a useful addition to the library of the biologist.

CHAS. B. DAVENPORT

NEW MANKILLERS[1]

THIS is a very interesting book. It contains much material informative to those not already familiar with the field covered. There are relatively few errors of statement.

Unfortunately, the authors were limited by choice, or otherwise, to about 150 pages in which to present a topic almost encyclopedic in scope. They present various phases of their subject under the chapter headings: the soldier, man-made killers, the machines of modern warfare, crucibles of death, the chemical industry. These chapters are followed by an appendix and a bibliography. The topics discussed progressively increase in scope and in unsatisfactory treatment.

Chemical warfare is discussed under the somewhat lurid title of "Crucibles of Death," and attempts to cover in 40 pages the history of the development of chemical warfare itself, the great variety of materials used, and the tactics of their use.

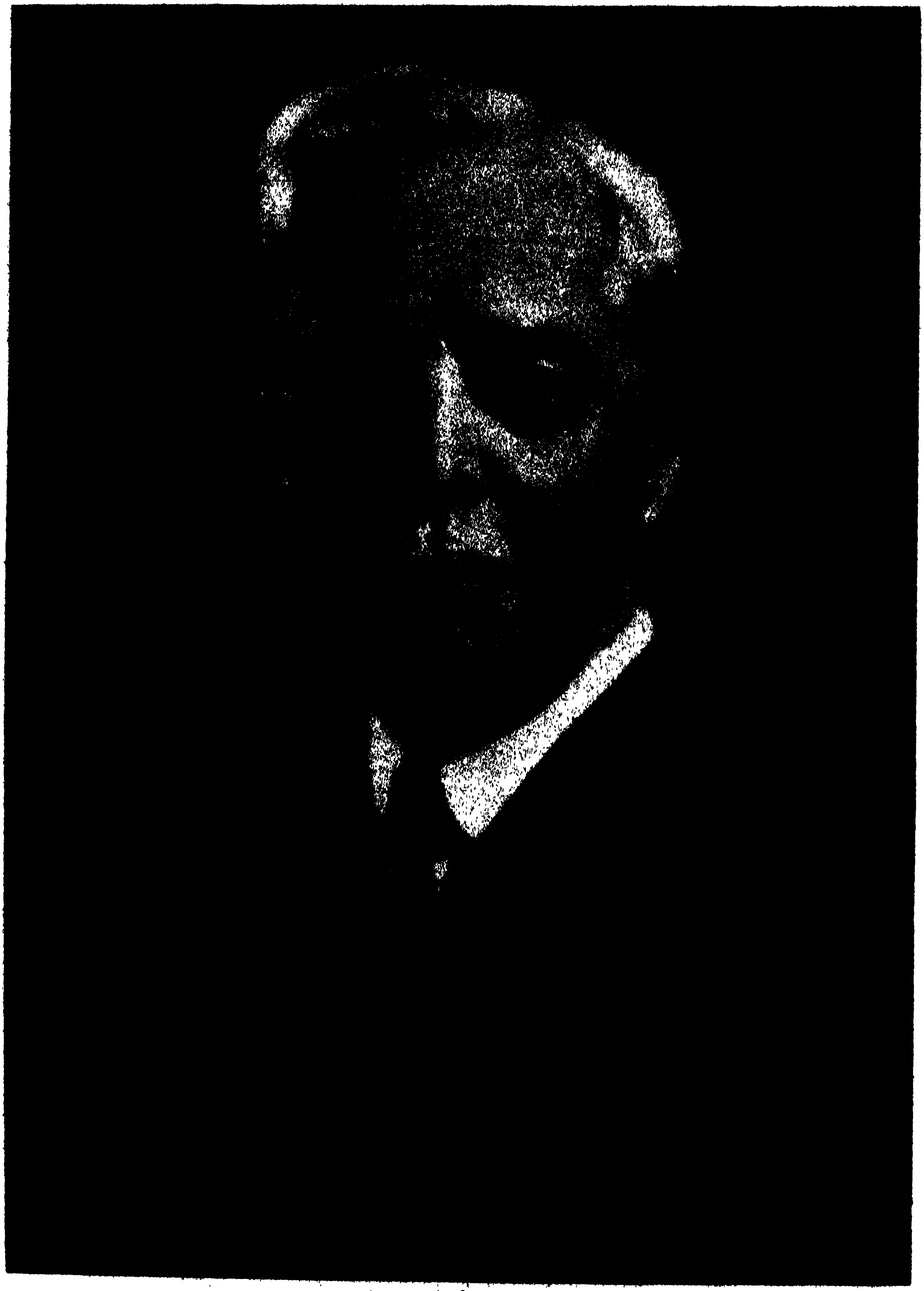
The 16 pages devoted to the chemical industry contain a collection of fragmentary data. The 23 pages of the Appendix give technical information concerning a wide range of topics. The attached bibliography may constitute the more important sources from which the data in the book have been collected, but almost no specific references are given in the text. Throughout the book there is an obvious attempt to laud the work of American chemists and to present this laudation in a colorful manner.

With so many attempted objectives it is not surprising that the authors have attained none of them in a very satisfactory manner.

Despite the severity of the criticism implied and expressed above, the book is not without considerable merit. It provides the technical man with a few hours of very interesting reading and permits an appreciative evaluation of the topics outside his particular field. The non-technical reader may not gain much actual information, despite the popular style of the book, but will probably get a better appreciation of the tremendous impact of modern war on the civilian population and of the importance of technical preparation and of capacity for production of war materials.

HORACE G. BYERS

[1] *Chemistry in Warfare: Its Strategic Importance.* F. A. Hessel, M. S. Hessel and W. Martin. Illustrated. 184 pp. 1940. Hastings House.



DAYTON CLARENCE MILLER

DAYTON CLARENCE MILLER, RENOWNED PHYSICIST

THE Case School of Applied Science suffered a great loss in the death of her noted physicist, Dr. Dayton Clarence Miller, on February 22, at the age of 74 years.

Dr. Miller had taught at Case for more than fifty years and had been head of the department of physics from 1893 until his retirement in 1936. In 1927 he had been made Ambrose Swasey research professor of physics. Upon his retirement the Case trustees bestowed upon him the title "Honorary Professor of Physics" for life, and at their request he continued as acting head of the department until the fall of 1939.

Internationally known for his work in quantitative measurements of light and sound and as the inventor of the Phonodeik, which turns sound waves into a moving beam of light upon a screen, Dr. Miller was at the same time a modest and lovable teacher, always searching for the truth and ever interested in the problems of his students.

Dr. Miller's work in the field of acoustics was widely recognized. He studied acoustics in relation to auditorium design and drew the sound specifications for some of the large auditoriums throughout the United States. Among these auditoriums are Severance Music Hall, the Epworth-Euclid Methodist Church and the First Church of Christ, Scientist, in Cleveland, and the chapels at Denison University, Bryn Mawr College, Princeton University, the University of Chicago, and he was consulted concerning the acoustics of the National Academy of Sciences building in Washington, D. C. In addition to these major structures, Dr. Miller designed specifications for about a hundred other churches, theaters, hospitals, offices and large and small auditoriums.

Another achievement was in his research on "ether drift," in which he sought proof of the earth's motion through the ether of space. This research followed the famous Michelson-Morley ether drift experiments of 1887, which originated on the Case campus. This research, both in Cleveland and at Mt. Wilson in California, was carried on by means of the interferometer, a mechanism which splits a ray of light into two parts traveling at right angles to each other. These beams are reflected back and forth by mirrors over a distance of 200 feet. Dr. Miller's ether drift studies, beginning in 1901, were led to the conclusion of a positive drift, on which he presented a paper before the National Academy of Sciences meeting at Princeton University on November 18, 1929. Full publication of these studies was made in 1933.

Dr. Miller was a member of many learned societies, including the National Academy of Sciences, and in several he held important offices. For three years he was chairman of the Division of Physical Sciences of the National Research Council of Washington. Since 1914 he was a member of the council of the American Physical Society, and served as secretary from 1918–1922, vice-president in 1923–24 and president in 1925–26. He served as secretary of the physics section of the American Association for the Advancement of Science in 1902–06, was vice-president in 1907, was secretary of the council in 1908 and general secretary in 1909. Besides membership in these societies, Dr. Miller was a member of thirty-three other organizations whose interests lay in the fields of physics, astronomy, acoustics, optics, engineering education, mathematics, scholarship and music.

Dr. Miller's degrees are many. He graduated from Baldwin-Wallace College with the degrees of bachelor of arts in 1886 and master of arts in 1889. In 1890 the degree of doctor of science was

conferred upon him by Princeton University. Since then he has received five honorary degrees: doctor of science from Miami University in 1924; from Dartmouth, in 1927; doctor of laws from Western Reserve University, in 1927; and the same from Baldwin-Wallace, in 1933. Case School of Applied Science conferred the degree of doctor of engineering in 1936.

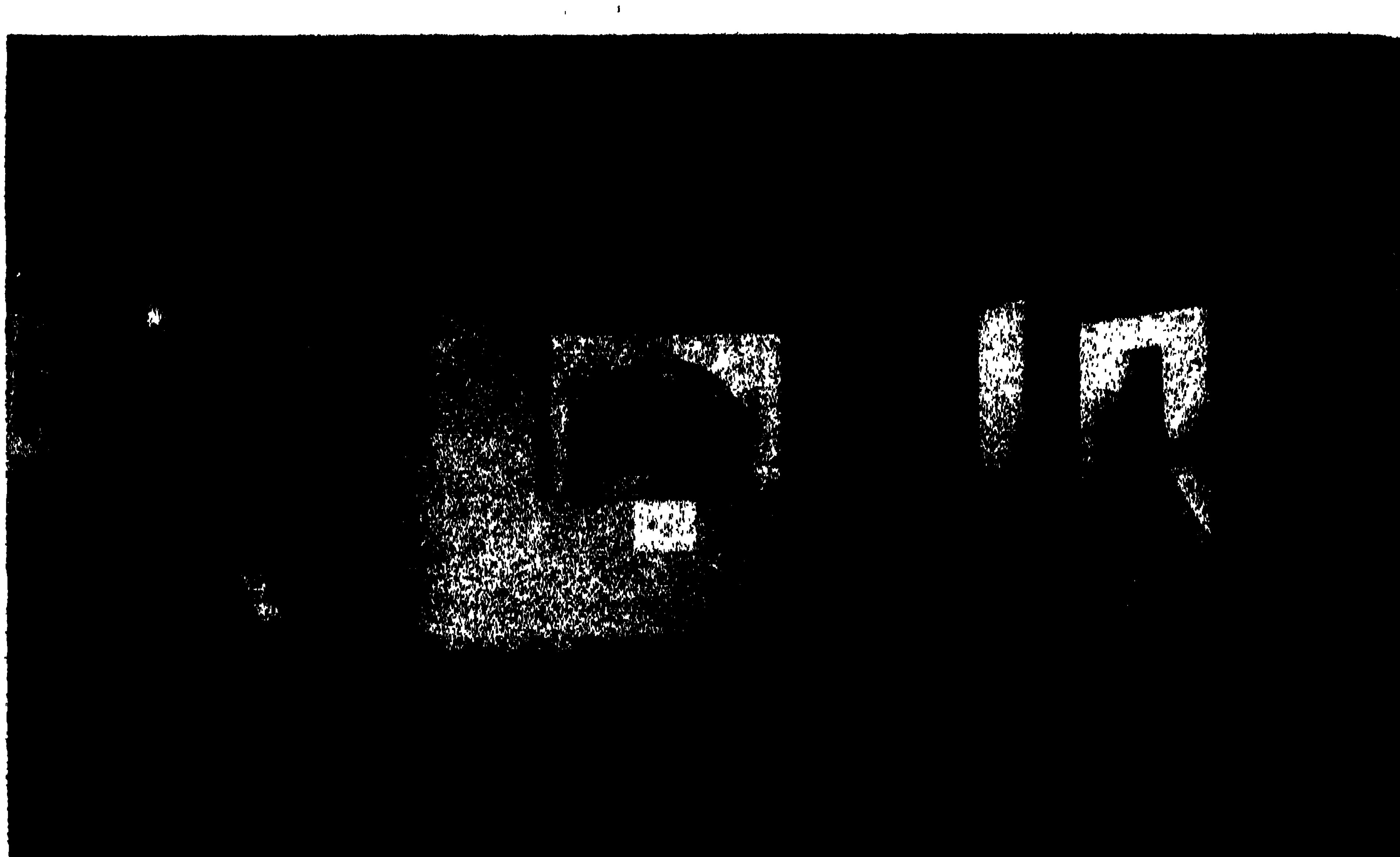
In addition to his many degrees, Dr. Miller possessed several medals for distinction in his scientific work. In 1917 and again in 1927 two medals were presented by the Franklin Institute. In 1925 he won the $1,000 prize of the American Association for the Advancement of Science, and the City of Cleveland gave him the medal for distinguished service in 1928.

W. E. WICKENDEN
PRESIDENT, CASE SCHOOL

ASTRONOMY SECTION OF SMITHSONIAN'S NEW INDEX EXHIBIT

THE purpose of the new index exhibit in the main hall of the Smithsonian Institution in Washington is to provide for visitors a concise portrayal of all the activities of the institution. The subject of each section of the exhibit is announced in large letters at the top of the panel, with a brief definition of the science or other activity below this title. Each section is developed around a central theme, which symbolizes the subject represented by means of a working model, diorama, painting or other medium. Flanking this on either side are models, specimens, paintings and other objects to visualize the Smithsonian's contributions to the particular field of investigation. All the exhibits are recessed behind glass and illuminated from above or behind.

The first subject portrayed, astronomy, is defined as "the study of celestial objects." The central theme is a diorama measuring about 2×3 feet representing the central room of a hypothetical space ship. The observer, apparently looking out from the nose of the ship, sees before him, against a black background spangled with stars, the globe of the earth with its familiar con-



ASTRONOMY SECTION OF SMITHSONIAN'S NEW INDEX EXHIBIT

CROSS-SECTION OF A SMITHSONIAN OBSERVING TUNNEL

TO KEEP TEMPERATURE CONDITIONS CONSTANT THE DELICATE MEASURING INSTRUMENTS ARE MOUNTED INSIDE A TUNNEL NEAR THE TOP OF THE MOUNTAIN. THE SUN'S RAYS ARE REFLECTED BY MIRRORS. THE INTENSITY OF THE RADIATION IS RECORDED ON PHOTOGRAPHIC PLATES. CAREFUL STUDY OF THESE ENABLES THE OBSERVER TO CORRECT FOR LOSSES IN THE EARTH'S ATMOSPHERE.

SUN'S RAYS LIGHT THE EARTH

THE EARTH LIGHTED ON ONE SIDE BY THE RAYS OF THE SUN AS IT WOULD APPEAR FROM A HYPOTHETICAL SPACE SHIP.

tinents and oceans. The earth, revolving slowly, is brilliantly illuminated on one side and dark on the other. The label emphasizes the importance of the sun's rays to life on the earth.

On the left-hand panel are transparencies in color of two of the Smithsonian solar observing stations—one on pine-covered Table Mountain, California; the other on barren Mount Montezuma, Chile, near the great nitrate desert. Adjoining these a very complete model in diorama form visualizes a mountain-top observing tunnel at one of these stations. The cut-away side of the mountain reveals a cross-section of the tunnel with all the instruments reproduced in miniature. Even the beam of sunlight reflected in by the clock-driven coelostat appears in the form of a tiny strip of Cellophane. The intensity of the solar radiation, as measured by an electrical thermometer sensitive to one millionth of a degree, records itself automatically on photographic plates in these tunnels, and one of the actual plates is mounted below the model.

The right-hand panel displays two of the instruments constructed under my direction in the course of the Smithsonian's solar investigation, namely, the silver-disk pyrheliometer for measuring in calories the total solar radiation, and the solar cooker, one of a series of instruments devised to produce heat and power directly from the sun's rays.

ABBOT SOLAR COOKER

ON A CLOUDLESS DAY THIS MODEL CAN UTILIZE THE SUN'S RAYS TO BAKE A CAKE IN HALF AN HOUR OR RUN A SMALL STEAM ENGINE. LARGER DEVICES FOR DISTILLING WATER, COOKING, REFRIGERATING OR OPERATING STEAM ENGINES HAVE BEEN CONSTRUCTED AND DEMONSTRATED.

The astronomy exhibit is completed by two placards calling attention to the purposes and results of the Smithsonian's study of the sun.

C. G. Abbot,
Smithsonian Institution *Secretary*

THE SNOW MOUNTAINS—NEW GUINEA GROUP IN THE AMERICAN MUSEUM OF NATURAL HISTORY

This recently installed exhibit portrays alpine conditions in the center of New Guinea, an island about 1,500 miles long by 400 in greatest width, and lying just below the equator. Chains of mountains extend, like a backbone, along the length of the island, reaching their greatest height in the Snow Mountains of Netherland New Guinea, where six peaks are eternally snow covered. The highest, Mt. Carstensz, reaches an altitude of 16,600 feet. The southeast trade winds bring a dry season to parts of the south and southeast coasts, where savanna country prevails, but the rest of the lowlands are humid, with dense tropical vegetation. Going up from these lowlands, one passes through belts of oak and beech forests to pines, tree-blueberries and rhododendron, and finally to alpine grassland and snow.

The view in the group is looking southward across Lake Habbema, which reaches 11,000 feet above the sea, toward Mt. Wilhelmina, the third highest peak. In the left foreground is a dark forest

A VIEW OF MT. WILHELMINA IN THE SNOW MOUNTAINS

TO AN ORNITHOLOGIST NEW GUINEA RECALLS BIRDS OF PARADISE. HERE TWO SPECIES ARE SHOWN: A GROUP OF MACGREGOR BIRDS OF PARADISE PERFORMING THEIR COMMUNAL DANCE ON A PINE BOUGH, AND JUST BELOW THEM A LONG-TAILED, SPLENDID BIRD OF PARADISE.

of pine and tree-blueberry, festooned with liverworts and mosses and enlivened with orchids; at timberline this gives way to grassland with many brilliant flowers. On Mt. Wilhelmina itself, the last few thousand feet are bare rock, capped with snow. Around the lake marshy areas add to the diversity of the country.

New Guinea has an extraordinary richness of bird life, with perhaps 500 breeding species. Bird life especially

QUAIL FROM THE SNOW MOUNTAINS

DETAIL OF THE ALPINE GRASSLAND SHOWING TWO QUAIL WALKING AMID BUTTERCUPS AND DAISY-LIKE FLOWERS NEAR THE EDGE OF A DRIED-UP POOL.

characteristic of New Guinea includes the birds of paradise, honeyeaters, pigeons, parrots and lories, kingfishers, cuckoo shrikes and flycatchers. Examples of five of these groups are shown in the exhibit. Most of the birds shown have never been exhibited before. Four of them were unnamed before last year.

The group was collected in the course of Mr. Richard Archbold's third and most spectacular expedition to New Guinea, known as the Indisch-Amerikaansche Expeditie. The expedition, in cooperation with the Netherlands Indies Government, concentrated on an altitudinal survey of mammals, birds, plants and insects from sea level to snow line on the north slope of the Snow Mountains. The success of the whole expedition, as well as the collecting of the group, was made possible by the use of the large flying boat *Guba,* which flew the party of more than 100 men, including carriers and a military escort, to Lake Habbema, and supplied them with food for their stay of nine months. Here the *Guba* operated from a higher altitude than had any flying boat previously. To have even reached the points inland by boat and on foot, the only other modes of travel possible, would have been an achievement. By the use of an airplane the party had ample time for studies, and was able to send out in addition to specimens such bulky material as the accessories for the group.

A. L. Rand

JUNGFRAUJOCH, THE HIGH-ALPINE UNIVERSITY

On the Jungfraujoch, in Switzerland, at an altitude of 11,340 feet, there stands a castle-like, massive stone building of two floors, with a solid-looking tower. This is the High-Alpine Research Institute. A visit to this building reveals scientific equipment many a university would be proud of—practically installed working rooms and splendid laboratories with the most up-to-date instruments. High up in the tower is the library, a comfortable, oak-panelled room where innumerable volumes of scientific works are at the disposal of the scientists. A permanent supervisor is in charge; he is probably the "highest" beadle. For visiting scientists there are comfortable dormitories and two-berth cabins, as well as a kitchen for the preparation of their meals—things one does not usually associate with scientific research stations. Adjoining the building are stables where a certain number of animals are kept for experimental purposes.

Courtesy Willy Haller, Zurich

TRAIN OF THE JUNGFRAU RAILWAY IN SWITZERLAND BETWEEN KLEINE SCHEIDEGG AND EIGER GLACIER.

Although this building was only started in 1929 and completed in 1931, the history of the Jungfraujoch High-Alpine Research Station dates back to 1894. It was then that Adolf Guyer-Zeller, the creator of the Jungfrau Railway, undertook to support science in its endeavors to extend research to high altitudes. A clause of the railway com-

Courtesy A. Klopfenstein

THE ALETSCH GLACIER, FIFTEEN AND ONE-HALF MILES LONG

FROM JUNGFRAUJOCH, SWITZERLAND, CONVENIENTLY REACHED BY MOUNTAIN RAILWAYS, ONE ENJOYS A GLORIOUS OUTLOOK ON THIS GLACIER, EUROPE'S MOST GIGANTIC "RIVER OF ICE."

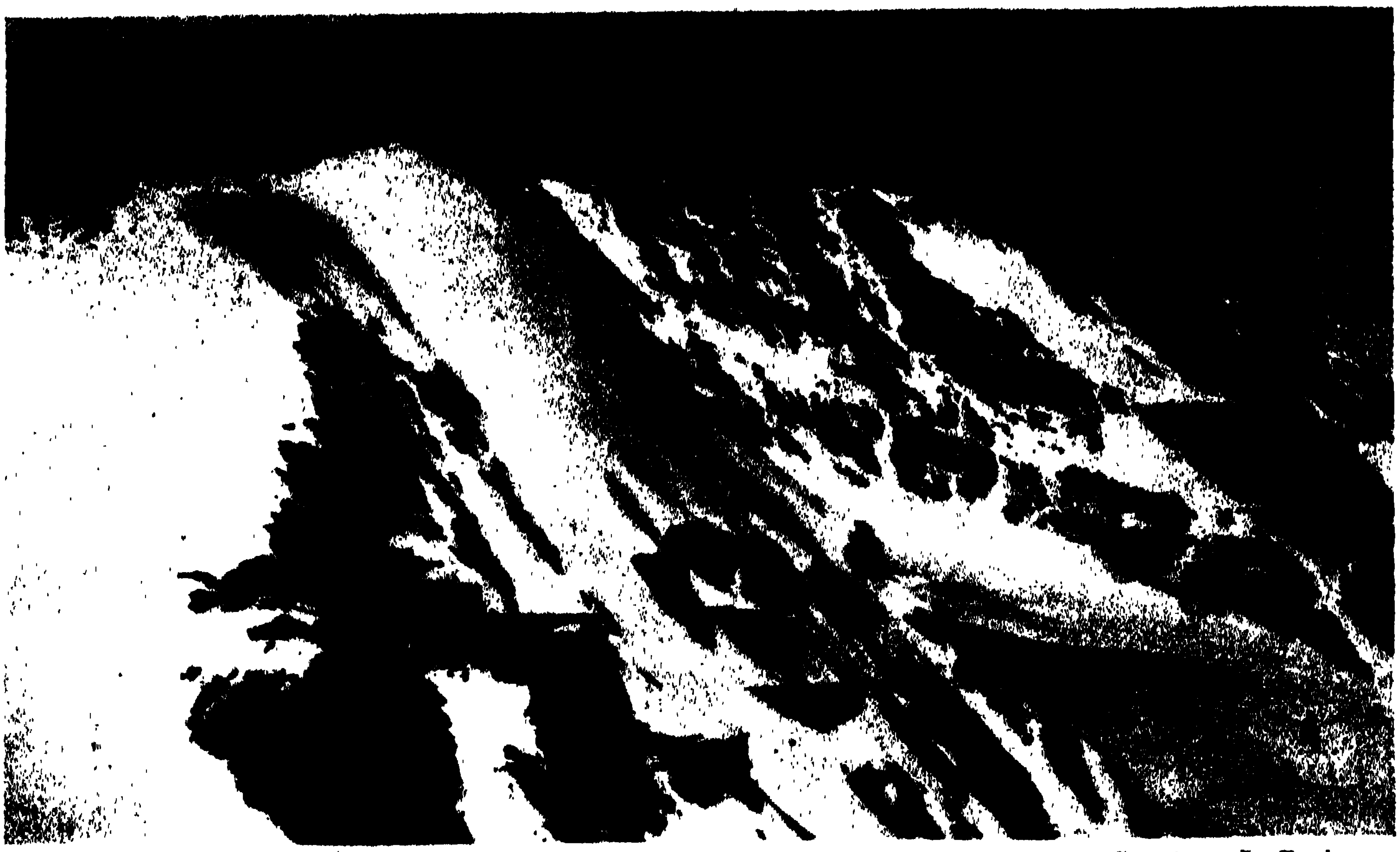
pany's concession obliged them to set aside considerable funds for the erection and the maintenance of a permanent observatory for meteorological and terrestrial-physical observations.

The Jungfraujoch Research Station was originally housed in a wooden pavilion erected on the plateau in 1925 by the Central Federal Meteorological Institute with the collaboration of the Jungfrau Railway Company. This was only a provisional arrangement until the meteorologists were able to take over their permanent home.

The Swiss Society for Natural History Research, which had been commissioned by the Federal Government to carry out the latter work, experienced great difficulty in finding a suitable site. The spot had to be freely accessible in all weather conditions. The solution was found by the Jungfrau Railway Company, when, in the spring of 1927, the "Sphinx" gallery was driven through to the Jungfraufirn. The new building was placed at the exit of this gallery. Thus the stately house on the south slope of the Sphinx came into being.

The institute undertakes research and investigations of a medical character, in physics (particularly cosmic rays), botany, zoology, etc. But astronomers also wanted to make use of this new home of science on the Jungfraujoch. The observatory of Geneva University accepted the task of installing a "branch" on the Jungfraujoch. Now a solid stone building is perched like an eyrie about 130 feet above the exit of the Sphinx gallery on the east slope of the Sphinx. But meteorology, which had been given priority in the Jungfrau Railway concession, was still without a home.

Unfortunately the Research Station itself did not possess the necessary funds wherewith to erect the required building. So "Sphinx Limited, Jungfraujoch" was formed in August, 1936, for the purpose of erecting the necessary buildings. Thorough investigation by famous meteorologists had led to the conclusion that the peak of the Sphinx would be the



Courtesy L. Beringer

SCIENTIFIC INSTITUTE AND NEW METEOROLOGICAL OBSERVATORY

JUNGFRAUJOCH, BERNESE OBERLAND, SWITZERLAND, 11,340 FEET, HAS THE LOFTIEST ALL-YEAR SETTLEMENT IN EUROPE. IT CONSISTS OF THE BERGHAUS HOTEL, THE JUNGFRAUJOCH RAILROAD STATION, THE HIGH ALPINE SCIENTIFIC INSTITUTE JUNGFRAUJOCH, AND TO TOP IT ALL, ON THE SUMMIT OF THE SPHINX ABOVE, 11,729 FEET, THE NEW METEOROLOGICAL OBSERVATORY JUNGFRAUJOCH.

most favorable spot for the new observatory. But again the problem of safety and accessibility had to be solved. A suspension railway from the Research Institute to the peak would have been too much exposed to weather and would have been useless at certain periods of the year. Thus it was decided to make use of the existing Sphinx gallery and to drive a shaft for a lift from here to the peak. In the summer of 1937 the erection of a solid stone building on the peak of the Sphinx, 11,716 feet above sea level, was completed. The observatory is at the free disposal of the Foundation "High-Alpine Research Station of the Jungfraujoch" and the Central Federal Meteorological Institute. Meteorological observations and weather forecasts from the peak of the Sphinx mountain are not only very important for mountaineers and skiers, but also render invaluable services to international aviation. The Swiss Alpine Club expressed its great interest in the erection of the meteorological station on the towering rock of the Jungfraujoch by subsidizing the scheme with a substantial amount of money.

Nowadays the Jungfrau Railway conveys not only numerous tourists to the lofty heights and beautiful Alpine scenery of this glacier district, but also an ever-increasing number of explorers and scientists eager to extend their investigations to hitherto unknown regions. During the five years since its completion, 184 scientists from every part of the world have taken advantage of this unique opportunity to carry out research work at this high altitude under the most auspicious conditions. They all study the same theme, namely, the influence of high altitudes on men, animals and plants, and apply the results for the benefit of humanity.

THE SPECTROSCOPE—THE MASTER INSTRUMENT

In the days of Newton the producers of refracting telescopes were in despair because when a beam of light passes obliquely through a refracting surface its direction is not only changed but it is spread out into its component colors. The result was that the refracting telescopes of the time formed separated images in various colors, each at a different distance from the objective, and consequently no definite focus was obtained. For this reason Newton and later Herschel turned to the use of reflectors which do not have this unfortunate property. It is altogether probable that observers of the time often thought that if they had directed Creation they would have had precisely the same refraction for all colors, and therefore much better telescopes for exploring the wonders of the heavens.

Alas for the silly opinion that man could improve on Creation! Dolland soon learned how to overcome largely the difficulties due to dispersion of light in refraction. And a thousand times more important, the dispersion of light of which the contemporaries of Newton complained was precisely the one of its properties that made possible the spectroscope, concerning which, upon receipt of the Rumford Medals of the American Academy of Arts and Science, Professor George R. Harrison, director of the Research Laboratories of Experimental Physics and of Applied Physics at the Massachusetts Institute of Technology, spoke in part as follows:

The spectroscope has become what appears to be the most powerful single tool which has yet been developed by the hand and mind of man, and one which is suited to a wide variety of purposes. Henry Norris Russell has called the spectroscope the "Master Key of Science," and an examination of the uses of the instrument reveals an astonishingly wide variety of applications. Recently I had occasion to list the various uses of the spectroscope; I found that it has been applied to such remarkably divergent purposes as the measurement of the ratio of the charge of an electron to its mass; determination of the weight of a star; detection of atoms present in a mixture of other atoms in amounts smaller than one in ten million; the measurement of the amounts of lead, arsenic and other poisons in foodstuffs; observation of the numbers of atoms entering and leaving molecules in a solution or vapor; calibration of the vitamin potencies of food samples; determination of the atomic constitution of complex molecules such as those of hormones and vitamins; measurement of the temperatures, sizes, distances and ages of stars; observation of the number and arrangement of electrons in atoms, and of atoms in molecules; the identification of criminals from traces left at the scene of a crime or carried from it; the study of the colors and discoloration of pigments and papers and ceramic glazes; the investigation of the origins and constitutions of minerals; and so on and on.

To the astronomer the spectroscope is at once a yardstick, a thermometer, a chronometer, a stethoscope for star-pulses, an analyzing microscope, a chemical balance and a super-telescope of the heavens. I think President Shapley will agree with me that though without the telescope the spectroscope would have little value to the astronomer, the spectroscope in its turn has multiplied the power of the telescope by perhaps twenty—for though it is the function of a telescope to gather light and focus this is an image or a spot, a spectroscope can separate this light into its component parts and thus lay bare a dozen meanings hidden from the eye.

To the physicist the spectroscope has served as a powerful atomic probe, for with its aid in analyzing the light emitted by atoms he has deduced much about their structures. He has found that light is emitted when atoms or molecules lose energy as the result of transitions of an electron from a position involving greater energy to one involving less; the spectroscope reveals the exact size of the photon which an atom emits under such circumstances, and by means of the quantum theory the physicist can picture what is going on in a tiny atomic system which is not more than ten or twenty billionths of an inch in diameter.

To the chemist, the biologist or the metallurgist, the spectroscope serves as a sensitive analytical instrument, to detect small amounts of impurities, or to analyze the atomic constitution of a speck of matter from its emission of light, or its molecular constitution from its absorption of light. Nor is the use of the instrument as a thermometer confined to the astronomer, for the engineer who wishes to determine the temperature of engine flames need only put a transparent window into the cylinder of a motor and use the spectroscope to study the light which is emitted.

F.R.M.

A NEW METHOD FOR STAINING CHROMOSOMES AND NUCLEOLI

Many of the advances in biology have depended on the development of a new technique or method. This is particularly true in cytology, where everything depends on getting a clear picture which will show the exact relationship of the parts studied. Further advances in the study of nuclear structure are made possible by the development of a new staining method which sharply differentiates the nucleoli from the chromosomes in a cell nucleus.

With the gentian violet-iodine staining method, which has been widely used by cytologists during the last fifteen years, the chromosomes and nucleoli stain alike, whereas with the new Feulgen-Light green stain the chromosomes are red and the nucleoli green. This result was attained by first staining with Feulgen, which is a specific stain for chromatin. The chromosomes are stained a bright red and all other parts of the cell are unstained. This is followed by the use of a mordant—5 per cent. sodium carbonate—which gives the nucleoli an alkaline reaction. The material—sections or smears of tissue—is left in the mordanting solution for an hour or more. The most satisfactory length of time varies from one genus of plants to another.

After thoroughly washing out the sodium carbonate, the material is stained for about ten minutes in an alcoholic solution of light green. This stains only the nucleoli and the matrix, or sheath around the red chromatin core of the chromosomes.

In recent years it has been shown that the nucleoli arise from chromosomes which have a satellite. This is a small globule of chromatin attached by an extremely delicate thread to the end of the chromosome proper. The nucleolus takes its origin, at least in many cases, from the tip of the chromosome at the point where the satellite thread emerges. With the new stain the origin and growth of the nucleolus can be followed from its earliest stages. In early telophase of mitosis all the nucleoli are separate, each being produced by a different chromosome. Such chromosomes have either a satellite or a secondary constriction producing a nucleolus farther from the end of the chromosome.

It is now known that in a number of genera, such as Oenothera and Oryza, which are generally regarded as ordinary diploid plants with only two sets of chromosomes, there are four chromosomes which each produce a nucleolus. Later, in the resting stage of the nucleus, they are generally fused into one. The presence of four is an indication that these plants are secondary tetraploids in which some of the chromosomes are represented four times. In rice particularly we have shown that the twelve pairs of chromosomes must have been derived from an ancestral condition with five pairs, which is the basic chromosome number for the whole grass family. It has similarly been shown that four is the basic number for the Leguminosae.

The Feulgen-Light green stain has now been applied to a long series of plant genera. It is found that the study of satellites and nucleoli by this method throws a great deal of light on the origin and relationships of plant species and genera and is of great value in the tracing of nuclear phylogeny. It is believed that the stain will be equally useful in animal cytology.

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SALT OF THE EARTH

A recent report by O. F. Poindexter and R. A. Smith on the enormous salt deposits in Michigan contains, by implication, a marvelous story written by the geologic processes some 400 or 500 million years ago.

In the Salina Basin alone there is an area of about 30,000 square miles in which deposits of salt have an aggregate thickness ranging from 500 to 1,200 feet. Conservative estimates place its total volume at 3,000 cubic miles, and its weight at 480,000 million tons. There is, therefore, no occasion for worry lest salt, an indispensable natural resource, will be exhausted, for this deposit alone is sufficient for the physiological needs of the whole human race, at its present numbers, for 200 million years. In addition, there are other comparable deposits of salt in various parts of the earth, not to mention enormously greater amounts in the oceans. In some regions, however, salt has been so scarce as to have been in earlier days an almost precious commodity.

Concentrations of salt, like those of other minerals, have been produced by the leisurely action of geological agencies. On the whole the history of salt deposits has been comparatively simple. From very ancient geological times, at least 2,000 million years ago and possibly from a billion years farther back, the waters that fell as rain or snow gradually disintegrated rocks and carried salt and other compounds dissolved out of them into the sea. By 500 million years ago the oceans had acquired a considerable degree of salinity. At that time life had been in existence on the earth for at least 1,500 million years, during which it had evolved from the low level of the blue-green algae up to that of corals and trilobites.

Even as early as 500 million years ago the lowly organisms that had lived up to that time had been important geological agencies and had produced astonishing results. For example, certain forms had precipitated the lime that is still spread in layers hundreds of feet thick over areas of hundreds of thousands of square miles. And, too, it was certain forms of life, bacteria, which were instrumental in the final concentrations of iron in such ores as those of the Lake Superior District. But salt had a more lowly origin; it was precipitated from the vanishing waters of drying seas. At the beginning of the Ordovician period, about 450 million years ago, nearly two thirds of what is now North America lay beneath the waters of a shallow sea. For 200 million years the waters several times alternately withdrew and spread widely over the continental area. In some of these great oscillations there were arid periods during which the water was evaporated from land-locked areas, leaving behind the salts that were dissolved in it.

Many substances are in solution in sea water, the most abundant of which is ordinary salt. There is, in addition, about one seventh as much magnesium chloride, one sixteenth as much magnesium sulfate and lesser amounts of compounds of calcium and potassium. If these various substances were left mixed together by vanishing seas, the difficulty of separating them now would be great. But they are precipitated at such different concentrations that often in the slow process of evaporation they are almost completely separated. It is because of this fact that there is now in Michigan enough almost pure salt to meet the requirements of the human race for many tens of millions of years.

The fact that the salt in Michigan was deposited during long arid periods raises the question whether the rains may not fail again over most of North America. No scientist would assert that they will not cease to fall in some remote future, perhaps for long intervals. But there is no thought that the droughts of the past few years is the beginning of such an era, for it is almost certainly a temporary deficiency produced by many minor cycles. For the near future, there is little danger; in long intervals great

changes are probable, changes that may make large areas of the earth uninhabitable by higher forms of life.

Indeed, we may look beyond the earth for possible causes of disaster, because our sun and its retinue of planets, according to recent conclusions reached at the Mount Wilson Observatory, make a circuit of our galaxy in about 200 million years. In such wide excursions among vast nebulae and billions of stars there are possibilities of an immersion of our system in wide-spreading nebulous materials and even of a disastrous collision with another star.

It is not intended, however, to emphasize the existence of that "bourne whence no traveler returns," for as a matter of fact science marks out a pathway that will be pleasant for those who take it. It is dissipating with light the superstitious fears that throughout history have darkened the lives of mankind.

F. R. MOULTON

EUGENICS AND WAR

WHILE there is yet time it behooves us, as eugenists, to consider our attitude not only to the war which is being waged to-day but to war as an expedient for settling the differences between nations. The problems are, in fact, bound up closely together, for among the issues in this war of opposed and utterly irreconcilable philosophies not the least important is that which divides those who believe in war as a virtue and favor political and economic systems that turn this virtue into a recurrent necessity from those who regard war as a barbarism and the eradication of the causes of war as the supreme duty of civilized men and women. By the time these lines are published it is possible that we may all be a little more concerned with the impact of war on our personal lives than with its influence on the numbers and transmissible qualities of generations yet unborn; but at this eleventh hour we may still take a long-term view, fortified in our apparently academic reflections by the knowledge that upon our conclusions on the wider issue will depend in large measure the resolution, steadfastness and spiritual conviction with which we shall face our immediate peril.

The view that war is not necessarily dysgenic, indeed, that it may actually favor the survival of the best physical and intellectual types, is argued ably and with a commendable absence of dogmatism in a letter published elsewhere in this issue. The author suggests that war, being in fact "Nature's usual way of solving the problem of which body of organisms is best fitted to survive within a certain set of circumstances," may be equated with natural selection, and asks how an expedient which ensures the survival of "the nation possessing the best brains and the best bodies" can properly be described as dysgenic. . . .

It is not necessary to consider in detail the points at which the analogy between war and natural selection breaks down. The survival of the fittest does not mean the survival of the best; it means the survival of those who are best adapted to the conditions of their environment. When man and pathogenic bacteria occupy the same ecological system, the death of the former and the survival of the latter is indubitably an instance of the survival of the fittest; but only on the most gloomy view of human nature could it be regarded as satisfactory proof of the survival of the best. Biologically speaking, the term fittest is meaningless except in relation to some particular environment, natural or social. In a world which regards war as desirable and its frequent occurrence as inevitable, the more aggressive and insensitive types have the best chances of ultimate survival. They are able to devote themselves to the congenial tasks of perfecting the weapons of destruction, while their more imaginative and gentler neighbors engage in the suicidal occupation of adding to the amenities and fullness of life. But though, unhappily, all this must be conceded it is not less true that the creation of a world in which love and virtue have a greater survival value than hatred and brutality is still within our power.—*The Eugenic Review (London).*

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ANCIENT FINGER PRINTS IN CLAY

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WHERE men are and where men have been there occur various traces, or tracks. The traces to be considered here are of a single kind, impressions of the fingers[1] on things which have been handled or touched. A finger may leave its imprint as a transferred film of natural skin secretions or of some other medium with which the finger has been smeared, and if the digit is pressed into a plastic substance such as clay its impression is then in the form of a mould, shallow or deep in accord with variable conditions of imprinting. These moulds of human fingers are of special interest as traces, since in clay they may be preserved through the centuries. A few examples of ancient prints are presented, not only for their intrinsic interest but to provide the setting for discussion of a moot question in finger-print history, as to whether such prints in clay ever were made with an aim comparable to that of present-day identification.

Certain principles of identification method must be first introduced. For the registration of individuals, whether in criminal or non-criminal files, impressions of the digits are printed on cards, usually in ink. All ten digits are recorded in orderly series and with care to ensure that the details of the ridged skin are clearly and fully imprinted. Filed according to a classification of the finger-print patterns which admits ready reference, the card serves thereafter as a means of proving the identity of the individual, since the making and classifying of his prints at any future date will serve to locate that record for comparison. It is possible also to classify and file separately the prints of single digits, to facilitate identification of finger prints found at the scene of crime. All original record prints and all prints taken from the person for later comparison naturally are made purposefully, for identification.

The second technical variety of finger prints embraces those imprinted without intention, termed chance or accidental impressions. These may be either latent, formed of the skin secretions alone, invisible without special preparation or at best faintly visible, or they may be of ink, paint, blood and like materials clinging to the skin. Only infrequently does the identification worker have occasion to deal with chance impressions in plastic substances. It is important to emphasize that chance prints are made, as their name indicates, in the course of ordinary contacts with objects. The reader holds the book open that he may read, the murderer grasps the gun with evil purpose, the glazier presses putty around the window glass to obtain a firm and neat seal—but no one of these intends to be making the finger prints which he leaves in the act. Chance prints are all about us in myriads, though most of them are incon-

[1] The word "finger" is used throughout in the generic sense which embraces thumbs as well as the fingers proper.

FIG. 1. LATENT PRINTS ON THE BACK OF A SHEET OF CHECKS*
DEVELOPED WITH SILVER NITRATE. THE SHEET, FROM A CHECK BOOK USED IN EXECUTING SEVERAL FORGERIES, HAD BEEN CARELESSLY HANDLED BY THE INVESTIGATORS. SUCH CHANCE IMPRESSIONS ON PAPER MAY BE LIKENED TO IMPRESSIONS PRODUCED IN THE HANDLING OF SOFT CLAY.

spicuous or invisible. If subjected to proper treatment, this page would reveal impressions, just as prints were developed on the sheet of checks illustrated in Fig. 1—an example which is not only a telling illustration of latent prints but a practical warning, in that investigators of a case of forgery carelessly handled these checks, obscuring a source of evidence with their own prints!

Having distinguished chance prints and those made intentionally for identification, it is to be emphasized that some impressions are identifiable, while some are not. To say that a print is identifiable does not mean necessarily that the identity of the maker can be disclosed, this being obviously impossible in the absence of some form of registration for reference; the point is simply that the print is technically adequate for comparison with another, to determine whether it is from the same digit or a different one. When prints are recorded for identification it is to be expected that they satisfy that purpose, but chance prints are often useless for comparison, since the markings of the skin ridges may be indecipherable or the available area lacking in sufficient details to establish identification. Ink prints, or developed latent prints, may be mere smudges or blobs, and prints in clay may be similarly devoid of ridge details, thus not being identifiable. We are to be concerned with both classes. In Fig. 2 there will be seen a complete and clear impression printed in ink, typical of the technique of identification records. The

* Fig. 1 is being used by courtesy of M. Edwin O'Neill and the *Journal of Criminal Law and Criminology*. Fig. 3 is from Badè, by courtesy of the Palestine Institute of the Pacific School of Religion. Fig. 4 is from Laufer, by courtesy of the Field Museum of Natural History. Fig. 5 is by courtesy of Professor A. D. Fraser. Fig. 6 is from B. C. Bridges and Fig. 7 from Earl H. Morris. Fig. 8 is by courtesy of the Middle American Research Institute, Tulane University. Photograph by Roy Trahan.

imprinted lines, which represent the summits of the delicate skin ridges, exhibit numerous "minutiae"—forkings, endings and abbreviations in length. Even a portion of such a print is identifiable when it contains a sufficient number of ridge details, individually distinctive as they are. The companion illustration is a blob, utterly useless for identification. With regard to prints in clay, it may be noted that occasionally (as in Figs. 3, 4, 5) they are identifiable, while others (Fig. 6) are featureless excavations in the clay, corresponding in their lack of individual markings to the blob made with ink.

Its documented history dating only from the latter part of the nineteenth century, the present finger-print system may have originated quite independently of finger-print practices followed long ago in the East. The history of these practices has been pieced through the efforts, among others, of the late Berthold Laufer, in his "History of the Finger-print System,"[2] of Robert Heindl, in the historical sections of "System und Praxis der Daktyloskopie,"[3] the most comprehensive handbook in its field, and of George Wilton, in the recent work, "Fingerprints: History, Law and Romance."[4] Their accounts contain descriptions of numerous instances of finger marks applied to deeds, contracts of loan and other documents; one example will suffice to illustrate the characteristic employment of these marks.

Wilton cites a Chinese contract of loan executed nearly twelve hundred years ago, bearing the prints of witnesses as well as those of the parties to the contract. Appended to the contract there is the formula: "The two parties have found this just and clear, and have affixed the impressions of their fingers . . ."; it concludes, still according to the Chavannes translation of the Chinese, "pour servir de marque." Assuming that Chavannes is correct in his translation, it appears that "pour servir de marque" must have meant only "to serve as a mark [token, or sign]," and that the sense of distinctiveness in Laufer's (1917) rendering of this phrase from the French ("to serve as a *distinctive mark*") is gratuitously introduced.

Wilton, who examined the document which bears the prints, remarks:

> Dr. Giles states that he is of the opinion that the fingermarks shown upon it are blobs and of no use for identification purposes. . . . To the eye of a layman, the fingermarks . . . do resemble blobs. With the magnifying glass, it is difficult to discern finger-ridge lineations. The marks seem to have been made more by the tips than by the bulbs or pads of the fingers. I do not think, however, that it would be reasonable to infer from the examination of this particular document that all fingermarks upon writings of the period in question were so blobbed as to make identification impossible.

Certainly Wilton is justified in insisting against any inference that prints made at that time were invariably mere blobs. Some examples, indeed, long antedating the inauguration of the finger-print system as we know it, are identifiable prints. It would be fallacious to assert positively that a print was not made for identification because it is a mere blob; while their occurrence is

FIG. 2. FINGERPRINT COMPARISON
A CLEAR PRINT, MADE IN INK, SHOWING RIDGE DETAILS, AND AN UNIDENTIFIABLE BLOB.

[2] Smithsonian Inst., Annual Report, 1912, pp. 631–652. This was followed up in a brief note by Laufer, *Science*, n.s., 45: 504–505, May 25, 1917.

[3] Berlin and Leipzig: Walter de Gruyter and Company, 3rd ed., 1927.

[4] London, Edinburgh and Glasgow: William Hodge and Company, Ltd., 1938.

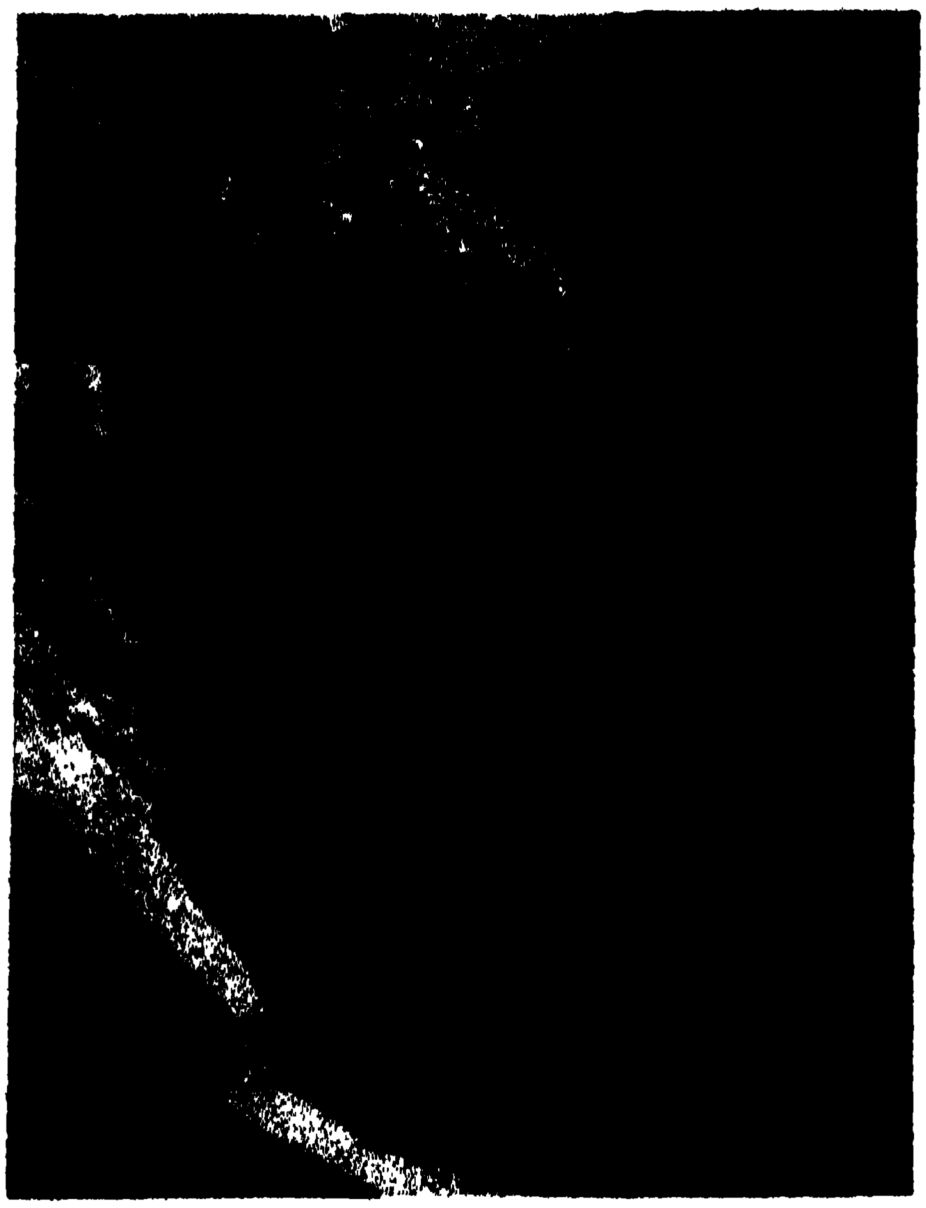

FIG. 3. ON PALESTINIAN LAMP
A CLEAR IDENTIFIABLE PRINT ON A FRAGMENT OF A MOULDED PALESTINIAN LAMP (BYZANTINE PERIOD, THE FOURTH OR FIFTH CENTURY A.D.).

FIG. 4. A CHINESE SEAL OF CLAY
MADE NOT LATER THAN THE THIRD CENTURY B.C. THE OBVERSE SIDE OF THIS CLAY PAT BEARS A SEAL-IMPRESSED NAME, PRESUMABLY THAT OF THE MAKER. WAS THE THUMB PRINT APPLIED AS AN IDENTIFYING MARK IN THE CURRENT SENSE OF FINGER-PRINT IDENTIFICATION?

exceptional, blobs are not unknown even to-day in official files.[5] It must be admitted that even if ancient records do bear an overwhelming majority of blobs, rather than clear prints, the frequency of the fault is not a final argument for lack of intention to make identifiable prints. Borrowers and lenders thus signed their notes, buyers and sellers applied prints to deeds, and in these and other transactions the prints of witnesses sometimes were added. If there were a finger-print science in their times expertness in its methods hardly could have been a qualification of many signers, busily occupied with other affairs! Even now there are persons who have the notion that any finger mark, however blurred, is fit for identification, and the product of their finger-printing might be no better.[5] On the other hand, it does not follow that the presence of clear details such as are found occasionally on other ancient documents, in China and elsewhere, is in itself evidence that the prints were made for true finger-print identification. Both clear prints and blobs alike may have established, in some instances at least, only what may be designated a "token identification."

Prints in old clay ware figured in the history of modern identification methods, to the extent that one of the pioneers of finger-print science was led to his investigations through an interest first stimulated by observing them. In 1880 Henry Faulds (1843–1930), a Scottish medical missionary then stationed in Japan, addressed a letter to the editor of *Nature*.[6] Among other matters of less immediate practical bearing, this letter directed attention to the usefulness of prints for

[5] For example, M. Edwin O'Neill (*Jour. Crim. Law and Criminol.*, 30: 929–940) reproduces the thumb prints accompanying the medical examination of a sailor in the Merchant Marine. The prints are solid blobs of ink which, like that shown here in Fig. 2, would be utterly valueless for identification.

[6] *Nature*, 22: 605, October 28, 1880.

personal identification, and in it Faulds related the genesis of his interest in finger impressions:

In looking over some specimens of "prehistoric" pottery found in Japan, I was led, about a year ago, to give some attention to the character of certain fingermarks which had been made on them while the clay was still soft. Unfortunately, all of those which happened to come into my possession were too vague and ill-defined to be of much use, but a comparison of such finger-tip impressions made in recent pottery led me to observe the characters of the skin-furrows in human fingers generally.

Anticipating the dealing with individual examples of finger prints on ancient clay seals and tablets, pottery, figurines and bricks, a preview of the possible explanations of their occurrence may be helpful. (1) It must be granted, as Laufer has pointed out, that there was recognition of the individual variability of finger-print characteristics before the inception of the modern identification system in the latter part of the nineteenth century. It is possible, therefore, that imprints on plastics may have been applied in some instances to serve for personal identification in the current sense, though definite evidence supporting this possibility would be difficult to produce. For the sake of brevity, the present-day method will be termed *finger-print identification;* finger prints made purposefully for identification according to its conventions will be designated *identifying prints.* (2) The symbolic associations of the fingers (and hands) appear to have been the motivation of at least some of the ancient recordings of finger marks, and some imprints in clay doubtless were of that import. The sense of "identification" is here quite different from that of finger-print identification. The primary in-

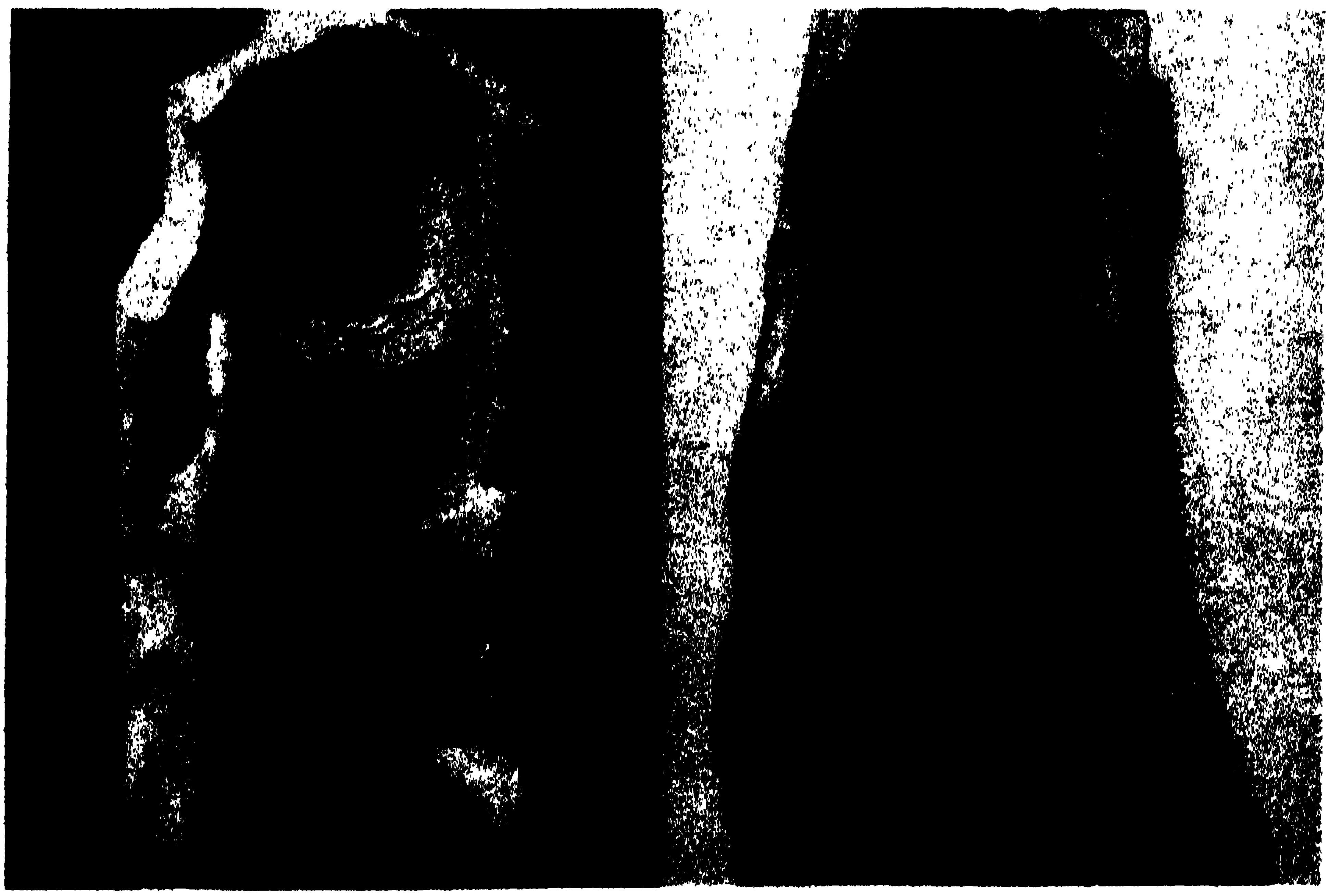

FIG. 5. FRAGMENTS OF TWO FIGURINES FROM SELEUCIA, MESOPOTAMIA
THE IMPRESSIONS ARE ON THE INNER FACES OF THE FIGURINES, THEIR SUCCESSIONS SUGGESTING THE MOST NATURAL AND EFFECTIVE WAY OF APPLYING THE SOFT CLAY WITHIN A MOULD OF IRREGULAR FORM. ENLARGED ONE AND TWO-THIRDS TIMES.

tent of such imprints would be simply to register *marks made by the person,* establishing the "sympathetic relation" as it is termed by Laufer, and if they proved occasionally to be identifiable prints that result was fortuitous. The finger prints, identifiable or blobbed, which served the purpose may be called *token finger marks,* and the "identification" afforded by them a *token identification.* (3) Since fingers are ever-ready tools it would not be surprising if they were used in certain instances for the making of recognition marks on plastic objects. Variable placings and different numbers of fingers plunged into the still soft clay of bricks, pots and other objects would make it possible to identify the makers or to designate other sortings of the products. Such marks will be distinguished as *finger signs.* But it should be apparent that finger signs are by no means comparable to the identifying prints of finger-print identification. Their purpose would have been accomplished as well if sticks instead of fingers had been employed for marking, unless there were involved as well some element of token identification. (4) Finally, considering that plastic clay has been worked into form by the fingers, it must be evident that a share of the prints preserved in the finished objects are chance impressions of these natural tools. Let us call them *chance prints,* signifying that as prints they were not applied purposefully, notwithstanding purpose in the act of grasping or modeling the soft clay.

In connection with finger prints in clay Laufer states:

> Finger marks may naturally arise anywhere where potters handle bricks or jars, but every expert in finger prints will agree with me that these are so superficial as to render them useless for identification. A clear and useful impression in clay presupposes a willful and energetic action, while the potter touches the clay but slightly. However this may be, we are not willing to admit as evidence for a finger-print system any finger marks of whatever kind occurring in pottery of any part of the world, unless strict proof can be furnished that such marks have actually served for the purpose of identification.

Laufer's general position on the evidential status of prints in pottery offers no ground for disagreement, but he is mistaken in the belief that chance prints on pottery are invariably useless for identification, as will be shown by example. And he is mistaken also in his analysis of the mechanical factors involved in the production of clear prints. On the basis of experiments with clay and other plastics, and by observation of imprints in pottery, the writer holds that so long as the imprinting finger is applied without dragging which would blur the print, the important factors determining clearness of the print are the texture and consistency of the clay. A coarse-textured clay will not yield prints which are identifiable, nor can even a fine clay if it is either of very thin consistency or too firm. Attention may be recalled, finally, to the two connotations of the word *identification.* The "strict proof" demanded by Laufer, "that such marks have actually served for the purpose of identification," is not lacking if we broaden the sense of the word to include token identification. Some ancient prints on clay, like those on the Chinese documents and the clay seal mentioned below, are pedigreed associations with particular persons, recorded with the object of "identifying" those persons with their contractual obligations. "Identification" of this sort bears a close relationship to the signing of a document by an illiterate. Neither a finger-print blob nor the illiterate's cross mark possesses qualities by which identification can be established objectively, yet each carries weight as a sign of bodily action of the individual. Finger-print identification is entirely objective, quite unrelated to the aims and procedures of the token identification

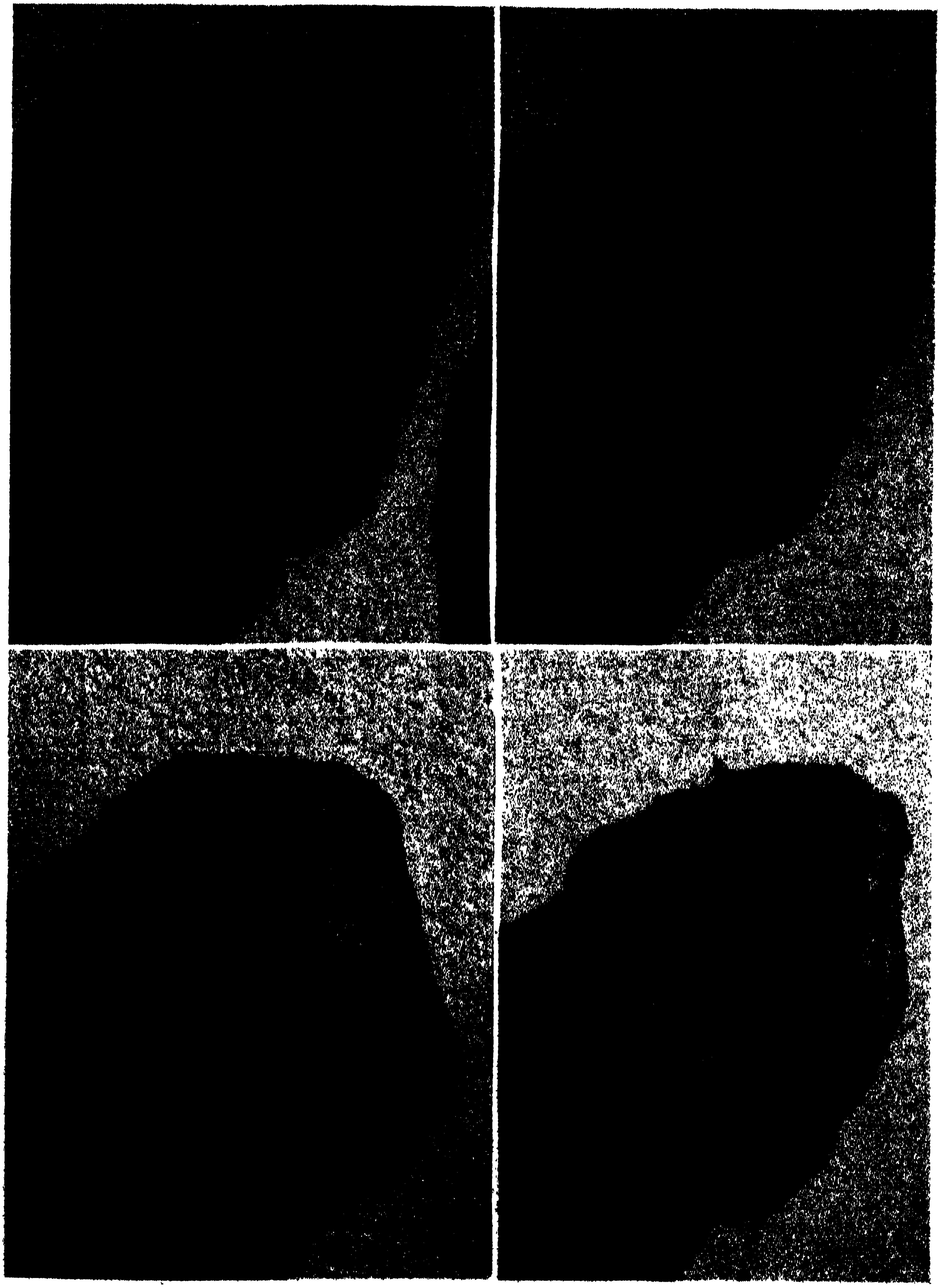

FIG. 6. AZTEC FIGURES, SHOWING DEPRESSIONS IMPRESSED BY DIGITS ON THE REVERSE SURFACE (ENLARGED ONE AND ONE THIRD TIMES).

effected by applying any sort of finger mark.

Among the clay objects which are of interest in connection with finger-print history are Chinese seals. Laufer presents an extensive discussion of such seals, and from his account the following information is taken. Prior to about the first century B.C. clay seals were used extensively in sealing documents, written at that period on slips of bamboo or wood, official letters and packages. Some among the several specimens specially described by Laufer were moulded around fingers, and there is one, thought to have been made not later than the third century B.C., bearing a firm, clear thumb print (Fig. 4). Laufer points out that the application of such a print and the manipulations of other examples indicate that "the primary and essential point in these clay seals was a certain sympathetic relation to the fingers of the owner of the seal." He continues:

> Here we must call to mind that the seal in its origin was the outcome of magical ideas, and that, according to Chinese notions, it is the pledge for a person's good faith; indeed, the word *yin*, "seal," is explained by the word *sin*, "faith." The man attesting a document sacrificed figuratively part of his body under his oath that the statements made by him were true, or that the promise of a certain obligation would be kept. The seal assumed the shape of a bodily member; indeed, it was immediately copied from it and imbued with the flesh and blood of the owner.

This thumb-print specimen, of all the imprints in clay known to me, is the only instance which seems entitled to serious consideration as a possible *identifying print*. Its importance is therefore such that Laufer's interpretation should be stated in his own words:

> It is out of the question that this imprint is due to a mere accident caused by the handling of the clay piece, for in that case we should see only faint and imperfect traces of the finger marks, quite insufficient for the purpose of identification. This impression, however, is deep and sunk into the surface of the clay seal and beyond any doubt was effected with intentional energy and determination. Besides this technical proof there is the inward evidence of the presence of a seal bearing the name of the owner in an archaic form of characters on the opposite side. This seal, 1 centimeter wide and 1.2 centimeters long, countersunk 4 millimeters below the surface, is exactly opposite the thumb mark, a fact clearly pointing to the intimate affiliation between the two. In reasoning the case out logically, there is no other significance possible than that the thumb print belongs to the owner of the seal who has his name on the obverse and his identification mark on the reverse, the latter evidently serving for the purpose of establishing the identity of the seal. This case, therefore, is somewhat analogous to the modern practice of affixing on title deeds the thumb print to the signature, the one being verified by the other. This unique specimen is the oldest document so far on record relating to the history of the finger-print system.

Not all these views withstand close examination. It is probable that the maker of the clay tablet was the person whose thumb print and seal it bears, though it is not impossible that two persons executing a contract might have cooperated in making the seal, the one impressing his name and the other his thumb. There is no reason to doubt that the thumb was impressed intentionally. Except in the area of the thumb print, the reverse face is rough, showing no evidence of having been surfaced with fingers or a tool. While this state might be regarded as an indication of purposeful recording of the print, neither it nor the quality of the print denotes unquestionably the designed recording of an identifiable signature. The possibility exists, of course, but there is nothing to support the interpretation that this particular impression is more meaningful as an evidence of early finger-print identification than are the other seals, and much to say against it, including Laufer's own statements on the symbolic significance of seals generally.

Fingers were sometimes impressed in ancient bricks of various localities, as in those from the storehouse of the first

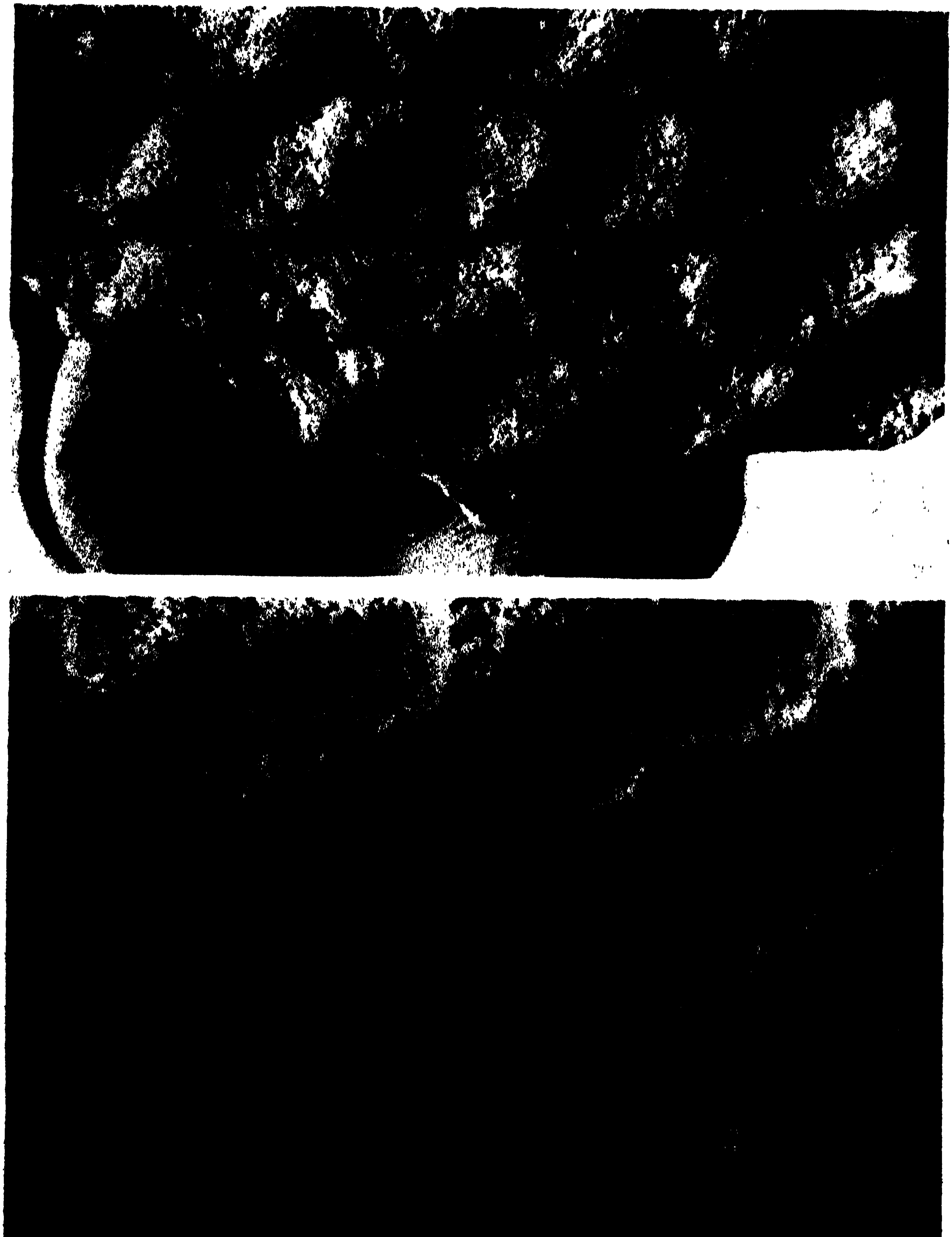

FIG. 7. SHERDS OF INDENTED CORRUGATED POTS, ENLARGED FROM THE LAPLATA VALLEY OF NEW MEXICO (EARLY PUEBLO III PERIOD, 900–1100 A.D.). THE THUMB IMPRESSIONS RESULT FROM USE OF THE DIGIT AS AN INDENTING TOOL.

king of the Lagash dynasty in Mesopotamia, dating from about 3000 B.C. These bricks are described by Handcock[7] as being plano-convex in shape, each bearing a digital impression on the convex face. Maspero,[8] in a general characterization of Egyptian bricks, states: "Bricks from the royal brickyards are occasionally stamped with the cartouche of the reigning sovereign, those from private factories are marked with one or more conventional signs in red ink, a print of the moulder's finger or the maker's stamp. The greater number have no mark." Birch[9] describes the unburnt bricks of the Southern pyramid at Dashour as mostly having been made of "rubbish, containing broken red pottery and pieces of stone." He asserts that: "The kinds were distinguished by *various marks made by the finger* [italics mine] on the brick before it was dry. In one instance this seems to have been effected by closing the fingers and dipping their points into the clay." Birch describes also Chaldean bricks, bearing "impressions of the five fingers, or of a circle, probably the brickmaker's private marks." Some writers on the history of finger-print science have cited these marks on bricks as evidence of early employment of finger prints for identification. Aside from the fact that rough materials used in brickmaking preclude identifiability of the prints, it is apparent that if the marks served as recognition signs their serviceability must have been on an entirely different basis from that of finger-print identification.

The Assyrian clay tablets on which were recorded in cuneiform symbols the terms of contracts, deeds and similar agreements bear "signatures" both in the form of personal seals and digital impressions (Maspero).[10] The fact that at least some of the impressions are but indents of the finger nails seems to point to their nature as token identifications.

The late William Frederic Badè, as director of the Palestine Institute of Archaeology, conducted at Tell en-Nasbeh excavations which have led to the identification of the area as the site of Benjaminite Mizpah, the capital of Judah after Jerusalem was destroyed by the Babylonians, 586 B.C. The excavations are exemplars of systematic method in the removal and careful indexing of enormous quantities of artifacts, of which pottery fragments represent a large share. Many of these fragments bear identifiable finger prints, on handles at the extremities where they had been attached to vessels and on the inside surfaces of moulded lamps, the latter being the more nearly perfect impressions. One print, here copied in Fig. 3, has been used by Badè as the frontispiece of his book, "A Manual of Excavation in the Near East,"[11] where its laconic label, "Finger print of a potter," tells all that can be said as to the identity of the man, only that it was he who moulded the ware. But repetitions of the prints on many different pieces tell further that it was this same forgotten potter who made them all—a finding which has been put to use in dating the origin of confused débris.

In discussing the prints found by Badè, Bridges[12] expresses his judgment that "these impressions were obviously intentional and, no doubt, represented the workman's individual trade-mark." The implication of the context is that the trade-mark would have been identi-

[7] "Mesopotamian Archaeology." New York: G. P. Putnam's Sons, 1926.

[8] "Manual of Egyptian Archaeology." New York: G. P. Putnam's Sons, 1926.

[9] "History of Ancient Pottery." London: John Murray, 1873.

[10] "Life in Ancient Egypt and Assyria." New York: D. Appleton and Company, 1899.

[11] University of California Press, 1934. (Badè's work is reviewed by an anonymous writer in *The Scientific American*, vol. 152, 1935.)

[12] *Finger Print Magazine*, 18: 11, 1937.

fiable as a finger print, though Badè has been quoted elsewhere[13] as saying: "I do not for a moment believe that the potters were aware that their finger prints had the distinctiveness which is now recognized in the finger-print system. It is the place and arrangement of the impressions which served as distinguishing marks to them." This view throws quite a different light on the significance of the prints in question; if serving as "trade-marks," it was not as finger prints *per se* that they proved useful, for if only their placing and arrangement supplied the identifying signs scratches or other markings could have served as well. It is not open to proof, of course, that the prints were impressed for this purpose. Regularity of their positions in the output of a particular potter, which is suggested in Badè's comment, might signify nothing more than regularity of habit in the manipulations of potting. In attaching a handle the potter must needs have impressed a thumb or finger in joining it and the vessel with a firm bond. His intention certainly was to join them, but the imprint was a by-product of the process. Likewise in moulding a lamp or other vessel, the intention was to determine a particular form, and prints would have been impressed in the contact.

In a study of the technology of Pecos wares,[14] products of our own prehistoric Southwest, Miss Anna O. Shepard deals with many different types, of which one is of present interest. In the construction of this type, coiled pottery, clay is manipulated into a thin roll which is coiled and welded in a continuous wall. The marks incident to this method of manufacture are effaced in the making of a smooth-finished vessel, but they may be retained, the successive coils then showing as horizontal corrugations or ribs on the surface. In the process of coiling decorative indentions may be added, these being depressions spaced at regular intervals on the coil, made with either a digit or tool. The pottery to which I shall refer is both corrugated and indented, the indentions having been made by the edge of the thumb. Two sherds are illustrated in Fig. 7. The one uppermost in the figure is of peculiar interest, not that the sherd is more noteworthy than the other but because of an accessory feature of the illustration. The photographer, quite unaware that his technique would make the picture the more useful in this discussion, had posed the sherd by pressing it against a lump of plasticine or similar material. The mass had been kneaded into convenient form to serve as a support, and as will be noted even in the lack of sharp focus at this deeper level, the plasticine bears clear impressions of the skin features of the photographer's hand. Being chance impressions, made in the process of an operation designed for another purpose than to produce the prints, they are exactly analogous to the more durable prints in the accompanying piece of pottery.

In keeping with her thoroughgoing attack in other particulars of ceramic technology, Miss Shepard has investigated these imprints with care, and she finds that they throw light on the operations of pottery-making. The directions of the lines impressed by the skin ridges at the edge of the digit admit reconstruction of the method by which the coil was welded and indented. This finding, significant as it is in historical ceramic technology, is not related to the aim in citing the corrugated indented pottery. Of interest at the moment is the bearing of the thumb impressions on questions of finger-print history. Small as they are, and though they represent the margin of the thumb rather than the ball

[13] *Science News Letter*, October 27, 1934.

[14] Pottery of Pecos (A. V. Kidder). Papers of the Southwestern Expedition, No. 7, Vol. 2, Part 2. Yale University Press, published for Phillips Academy, 1936.

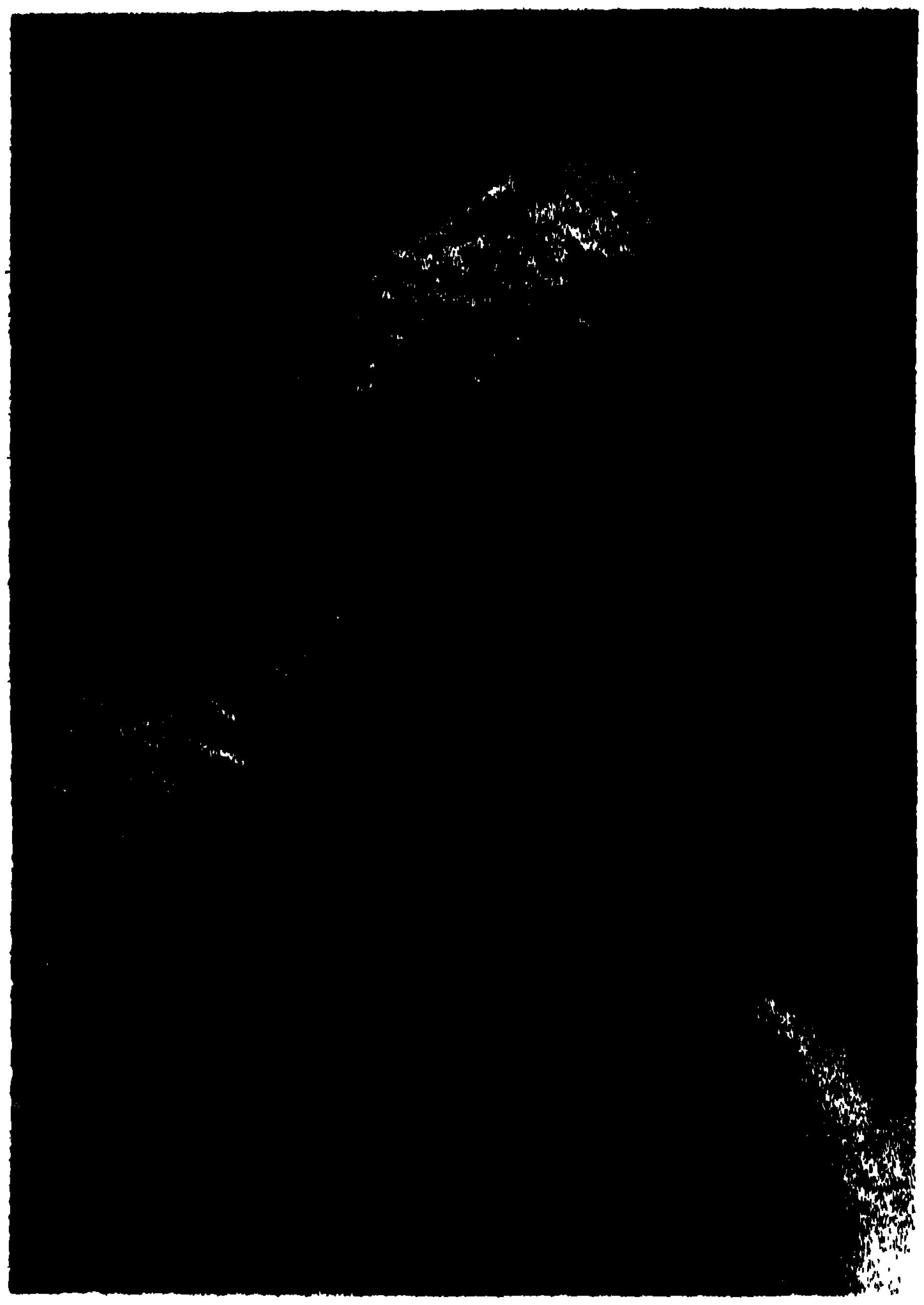

FIG. 8. IMPRINT ON CLAY HEAD
A CLEAR IMPRINT ON THE REVERSE SURFACE OF AN ANCIENT CLAY HEAD (MEXICO). THE FIGURE HAD BEEN MOULDED IN TWO PIECES, AND THE IMPRINT WAS CLEARLY MADE IN THE PROCESS OF JOINING THEM. ENLARGED FOUR TIMES.

where the pattern is located, the areas of impression in some examples show a few ridge details, which naturally are repeated time after time in the imprints of the digit. While the limited number of ridge details would not justify a positive identification under the ordinary conditions, their repeated occurrence on prints of the same sherd is itself strong evidence that they were made by one potter! The prints thus are identifiable, with reservations, but they were not made for identification. They were impressed in a potting method which makes use of the thumb as a tool. They are the exact equivalent, in origin, to impressions found, for example, on the edges of some old Roman pieces. Digits were employed in the making of scalloped borders, the finger prints resulting as the scallops were shaped. They are chance prints, no more significant from the standpoint of finger prints recorded for identification than are the short-lived impressions left by the cook in crimping the edge of a pie.

In an account dealing with small clay figures of Aztec manufacture, recently excavated in southern Texas, B. C. Bridges[15] considers that the impressions of fingers present on some of them may have been made as identifying marks, though he adds the qualifying reservation that it was "sometimes through accident," as well as "often by design, [that] the maker must have left upon these earthen forms the trademark of his finger prints." Of the seven specimens illustrated in his article, three bear finger impressions. Through his kindness I have received copies of the original photographs, from which two examples have been selected for reproduction (Fig. 6). Both are heads, and each shows on its reverse surface the mould of a digit. I have examined a large series of similar figures, in the Middle American Research Institute at Tulane University and elsewhere. Frequently the reverse surfaces of the objects bear excavations which clearly are impressions of fingers. But their occurrence, whether on heads of the type cast in clay moulds or on hand-modeled figures, leads only to the conclusion that the imprints are to be explained simply as chance marks of manufacture. At least some of the figures were cast in moulds, and the manufacturing significance of the indent of a thumb or finger is readily apparent. In so casting a small head the most natural procedure would be to use a digit in pressing the soft clay into the mould. In many specimens the finger imprints lack signs of the skin ridges, as if rubbing had effaced them or the clay were not of optimum consistency and texture to register these details.

[15] *Finger Print Magazine*, 20: 8, 1939.

One head which shows details was constructed in two pieces—the head proper and head-dress being joined after modeling. The details of the skin markings, reproduced in Fig. 8, are fairly clear. The imprint, far from having an identifying or symbolic connotation, is so placed on the back of the figure that its origin as a chance imprint produced in the joining of the two pieces is indisputable, as are those observed on a Toltec figurine, obviously associated with the joinings to the torso of the separately modeled head, arms and legs.

Through the kindness of Professor A. D. Fraser, of the division of archaeology at the University of Virginia, I am permitted to refer to an excerpt from an unpublished manuscript and to reproduce two photographs of finger prints impressed in clay. He writes:

> But occasionally the potter may impress his fingers in the clay after the wheel's revolutions have ceased; or he may jab a finger down hard against the interior of the aryballos for the purpose of flattening the exterior surface of the bottom, and thus supply us with the desired impression. . . . In the firing of Roman *terra sigillata*, the bowls were usually stacked one within the other and were supported on the finger-tips of the workman as they were placed in the kiln. As a result their under surfaces bear numerous prints; but these, owing to the condition of the glaze, as has been explained above, are in almost all cases mere smudges. But occasionally one is seen whose pattern is reasonably distinct. Our richest field for the study of dactyloscopy amid ancient ceramic products is found undoubtedly in the interior of figurines and lamps. As the figurine is the product of the hand of the coroplast, or of the hand aided by small modelling tools, the print-smearing wheel is not in evidence. The same thing is partly true of the ancient lamp and the plastic vase. . . . Frequently we find well-defined prints in their interiors. . . .

Two of Professor Fraser's specimens, of Mesopotamian origin, are shown in Fig. 5. The photographs represent interior surfaces of fragments of figurines, each showing the "inching along" of the potter's fingers as he pressed the soft clay into a mould. Again these finger prints are obviously nothing more than tool marks. Wilhelmina van Ingen,[16] in discussing similar figurines from the same locality, makes specific references to prints occurring on individually described examples and adds the following general comment on the method of manufacture.

> In the simplest of the mouldmade figurines the wet clay was pressed into a single mould, which gave the impression of one side of the figure only, usually the front. . . . The back was either roughly shaped by hand to be concave or convex, in which the maker's fingerprints are visible, or pared with an instrument.—In this process [the use of a double mould] separate moulds were used for the front and back halves of the figurine. The clay was pressed into each half of the mould, sometimes in several layers, to make a hollow shell (the fingerprints are always very clear).

There is no need to multiply instances further, describing more objects made of clay and extending the provenience in geography and time of those which carry finger impressions.[17] If not effaced by a finishing process or otherwise, imprints are to be found wherever plastic clay of suitable consistency and texture has been handled. In considering ancient examples there is danger of reading in

[16] "Figurines from Seleucia on the Tigris." Ann Arbor and London: University of Michigan Press and Oxford University Press, 1939.

[17] Among the examples recorded in the literature, additional to those mentioned in the text, the following may be noted: (1) Chance prints on bases of old Roman columns probably dating from the third century, A.D.—Sir William Turner. *Jour. Anthrop. Inst. Great Britain and Ireland*, vol. 30, new series, III, pp. 106–107, 1900. (2) Chance prints on a small vase of the neolithic period.—B. Males and M. Grbic. *Riv. d. Antrop.*, vol. 29, pp. 603–606, 1930–32. (3) Deep end-on excavations made by the finger tips, as by a dibble in soil, in the internal surfaces of Lake-dweller pots of the Bronze Age; from several to as many as 70 such pits occur in a single vessel; their purpose is problematic, but one of the suggestions advanced is the increase of heating area of the bottoms of pots used in cooking. Meisner [with important discussion by Kollmann], *Arch. f. Anthrop.*, vol. 27, pp. 120–122, 1900–1902.

them meanings which do not actually exist. While the historical uncertainties associated with their age offer a tempting ground for speculation, the availability of parallels in modern ceramics stands as a constant warning that too much license must not be allowed in interpreting such finger impressions. In my possession there are, for example, a tall Holland gin bottle with finger impressions so placed as to show that it was grasped and lifted before the plastic material had set, a clay jug with similar markings, a pottery cup having a finger-crimped border bearing a succession of prints, and two small moulded teapots which are literally covered with impressions of the fingers which formed them. In these there is not the slightest reason to believe that the finger prints were applied as identifying marks in any sense. If all the prints on old pottery are not to be explained on a like technological basis, and many of the recorded objects are best thus interpreted, it does not follow necessarily that intentional impressions of the fingers were made for the kind of identification which is practiced to-day. The intentional impressions fall into two classes: (1) merely symbolic personal marks, serving a token identification; (2) marks made for recognition, by spacing or number, as a tool might be used for that purpose. Finger-print identification in our usage of the term appears to have been practiced in a simple form in times long past, but some briefs for its claim to great age embody "evidences" which do not bear close scrutiny. The history of finger-print identification becomes shadowy as it is traced backward, and occasionally shadows of the remote past have been forced into standing for substance.

SCIENCE IN PEACE AND WAR

There is indeed a widespread recognition of the general effectiveness of science. The ways of using science and scientific men are being slowly discovered. But the process is slow. It would, I think, be hastened, if certain fundamental truths were generally known and recognized. I venture to state them in the form of a few propositions:

1. Science, that is to say, the knowledge of nature, is of fundamental importance to the successful prosecution of any enterprise.

For example, a nation is obliged to make all possible use of science in preparation for war, whether aggressive or defensive: and, again by way of example, in the maintenance of public health and social welfare. Of course, science is not alone in being a necessity in either case.

2. Science is of general application. There are not one science of chemistry, another of electricity, another of medicine and so on: there are not even distinct sciences of peace and war. There is only one natural world, and there is only one knowledge of it.

Experience shows that an advance in knowledge or technique or skill in any direction may be based on some item of knowledge acquired in a far distant field of research. For that reason, it is necessary to resist strongly a natural tendency for those who study science or apply it, to separate into groups without mutual communication.

3. Fruitful inventions are always due to a combination of knowledge and of experience on the spot. Unless the man with knowledge is present at the place and the time when some experience reveals the problem to be solved he misses the fertilizing suggestion. Neither can the mastering idea suggest itself to the man who has the experience only but no knowledge by which to read the lesson that the experience teaches. The man with knowledge may be a temporary or special introduction, or, much better, he may be the man who meets with the experience.

4. There are difficulties peculiar to the application of science to war purposes. While the war proceeds scientists as a body are anxious to put all their knowledge at the service of their country: but when the time comes they are anxious to get away to their work on pure science or the applications of science to the problems of peace. Government may preserve and most fortunately has preserved a nucleus of able scientific effort during the last 20 years of peace, so that a certain connection is maintained between these particular applications and the general body of science, but from the very nature of their respective occupations, and on account of a certain secrecy which one of the two bodies is forced to maintain, the connection is not always strong. It can easily happen that the solution of a particular difficulty in the war service may lie in some piece of knowledge far away from the immediate science of the enterprise and unknown to those who need it.—*Sir William Bragg in his anniversary address before the Royal Society of London.*

LAND TENURE IN TUNISIA

INTER- AND INTRA-NATIONAL IMPLICATIONS

By Dr. RAYMOND E. CRIST

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Where soil is, men grow,
Whether to weeds or flowers.
—*Keats, "Endymion."*

Even before the outbreak of the present war, France has persistently tried to "appease" Italy, in order, primarily, to have one less frontier to defend. Since the actual declaration of hostilities, Italy's leader has seemed to be too busy just keeping his country out of war to make demands on either Germany or the Allies. But this does not mean that Mussolini has given up all ideas of expansion in Mare Nostrum. Italian claims are only temporarily dormant. If it became apparent that Italian aid were necessary to the Allies for them to win the war a price would certainly be placed on such aid. And part of the price demanded by Italy would undoubtedly be that France relinquish Tunisia. Has Italy's "protective" instinct become aroused, or is the "Lebensraum" argument used in advancing this claim? A study of land tenure in Tunisia against its background of history and power politics may be revealing.

In April, 1880, the great estate of the Enfida, which comprised some 250,000 acres in the Sahel between Tunis and Sousse and belonged to the General Khayr-ed-din, was sold to a Marseilles Company for 2,000,000 francs. The bey of Tunis objected to the French that the estate had been given to the general for his own use, but that it could not be transferred to foreigners. The sale was held up by Yousef Levy, a naturalized English Jew, who claimed that he owned a plot of land bordering upon the Enfida, and demanded his legal right (chefâa), as an owner of adjoining property, to purchase the estate. England, who had till then given France a free hand, suddenly blew cold and sent battleships to Tunis to fight the French on this issue. The French allowed Levy to remain in control rather than fight England, but they bought his "rights" in 1882. Even before this was done France had beaten Italy to the draw. On March 30, 1881, several hundred Khroumirs in pursuit of tribal enemies in Algerian territory killed a few Frenchmen in an engagement with French troops. This was nothing new—border raids had been of almost daily occurrence for a decade. However, even if it was but a monotonous repetition of border forays, it was the necessary "incident." French troops occupied Tunis, and the bey had to sign the treaty of Bardo on May 12, 1881. Thus the climax in the last act in the drama of creating the French Protectorate over Tunisia was the sale of land to non-Moslems.

Systems of Land Tenure

According to Moslem law land is theoretically considered not to belong to any one. It belongs to God, whose representative on earth is the temporal ruler, who thus has the sole right to all "dead lands," *i.e.*, those which have not yet been "brought to life" by man. Once man has started to cultivate the land he may claim himself owner, and his private property is known as a "melk." Both custom and Koranic law recognize private property, the essential element of which is possession. Proof of possession, according to Koranic law, consisted in showing that one actually occupied the

VINEYARDS NORTH OF TUNIS

WITH THE PICTURESQUE NATIVE TOWN OF SIDI BOU-SAID IN THE BACKGROUND. SIXTY PER CENT. OF THIS LAND IS OWNED BY ITALIANS WHO HAVE DEVELOPED THEIR SMALL PLOTS PURCHASED FROM THE GREAT ESTATES OF FRENCHMEN.

land and used and enjoyed the fruits thereof. But since this right was a religious one, only Moslems could acquire title to real estate. It was only in 1857 that Mohammed Bey, "urged" by the French and British consuls and influenced by his minister, General Khereddine, promulgated the "Fundamental pact," which among other things extended the right to private property to all inhabitants of Tunisia, whatever their race, nationality or religion.

In any agricultural country such as Tunisia the question of land tenure is of fundamental importance. The system was of course not a simple one because of Moslem law and concepts of property, but geographic and historic factors added to the complications: for instance, the Bedouins of the steppes and the desert did not have the same concepts of ownership as the sedentary populations of the north. Furthermore, the local leaders in many instances had by their arbitrary actions further complicated situations that already seemed tangled beyond hope.

When the French entered Tunisia they found that among the populations in the densely settled areas of the northeast, of the Sahel and of the oases the concept of private property, or melk, was already deeply rooted. French law could here be readily applied, but in many cases the title to the land was not absolutely clear and it was necessary to secure the owners in their right. According to the law of July 1, 1885, each property owner could demand the registration of his property. An inquest into the papers, deeds, wills or other papers was held before a specially selected tribunal, and if the verdict of this body was to the effect that the papers were valid the title could be duly recorded in the "conservation fonciere." The title was then con-

sidered to be a clear one, and a new deed was given the owner. From 1885 to 1928 titles to some 1,300,000 hectares of land were thus cleared. But this is a relatively small amount when compared to perhaps 9,000,000 hectares of arable land in the Protectorate.

Acting on the Moslem principle that the land belongs to the sovereign, many beys had acquired large estates or had allowed their henchmen to acquire them. Since it was felt that these "crown-lands," so to speak, were the logical areas for colonization they were placed under the administration of the Department of Agriculture of the Protectorate. Thus it was hoped that there would be an opportunity for French colonization on such lands, which would not arouse the hostility of the natives. And in fact they have in many cases been favored by the change. A case in point is the huge domain of Ousseltia, northeast of Kairouan, where French colonists as well as landless natives have been granted land, and both have prospered. In the vicinity of Sfax, by regulating the "sialine" lands (great estates), the French local townspeople and even some former Bedouins have felt secure enough in their titles to the land to warrant their planting millions of olive trees.

In order to forestall the encroachment of the bey or sheik, or to prevent heirs from dissipating an estate, or to do a pious act, Moslem property owners often made an "Habou" of their property. The rules regulating this old Moslem institution could be complied with in two ways: the owner could either place the property in trust for his heirs, using only the income from it till his death, or he could cut off his heirs from all usufruct of the property, sometimes himself as well, in odrer to endow some public charity—usually a mosque, school or hospital. In the first case the Habou is private and the property is administered by the heirs or heir or by an executor. In the second case the Habou is public and is administered by the central office, the Djemaia, of the Habous, founded in 1874. The system of public Habous is quite similar to that of Mortmain in Spain, where gifts in land of wealthy persons, wills of pious members or last-minute death-bed gifts, in the course of centuries, made the Roman Catholic Church fabulously wealthy in real estate. And once this land was in the hands of the church it was not only inalienable but tax free (hence mortmain, "dead hand"). Some private Habous have become public as a result of the death of all the heirs.

Since land in Habous comprised approximately one third of the total area of the Protectorate the question before the French government was to get control of some of this land in order to settle Frenchmen on it. But bad feeling might be aroused if the French arbitrarily took over great areas of land and sold it to non-Moslems. So the first step was to give the natives living on either public or private Habous actual possession of their land. In many cases, although the natives had no title at all to their plot, their title was cleared by virtue of their having been on the land a long time —"occupants immemoriaux." But the cost of registering property is high: 5½ francs per hectare, 120 francs per plot or parcel, besides 5½ per cent. of the total value of the property. If there are a number of plots to be registered, the second must pay 132 francs, and any others 198 francs. Hence many natives could not afford to register the land on which they lived. Finally, by government decree of 1898, the sale or transfer, even to non-Moslems, of Habous—inalienable according to Moslem law—was legalized, and as a result large tracts of land have come into the hands of the Department of Agriculture of Tunisia and have been purchased by Frenchmen.

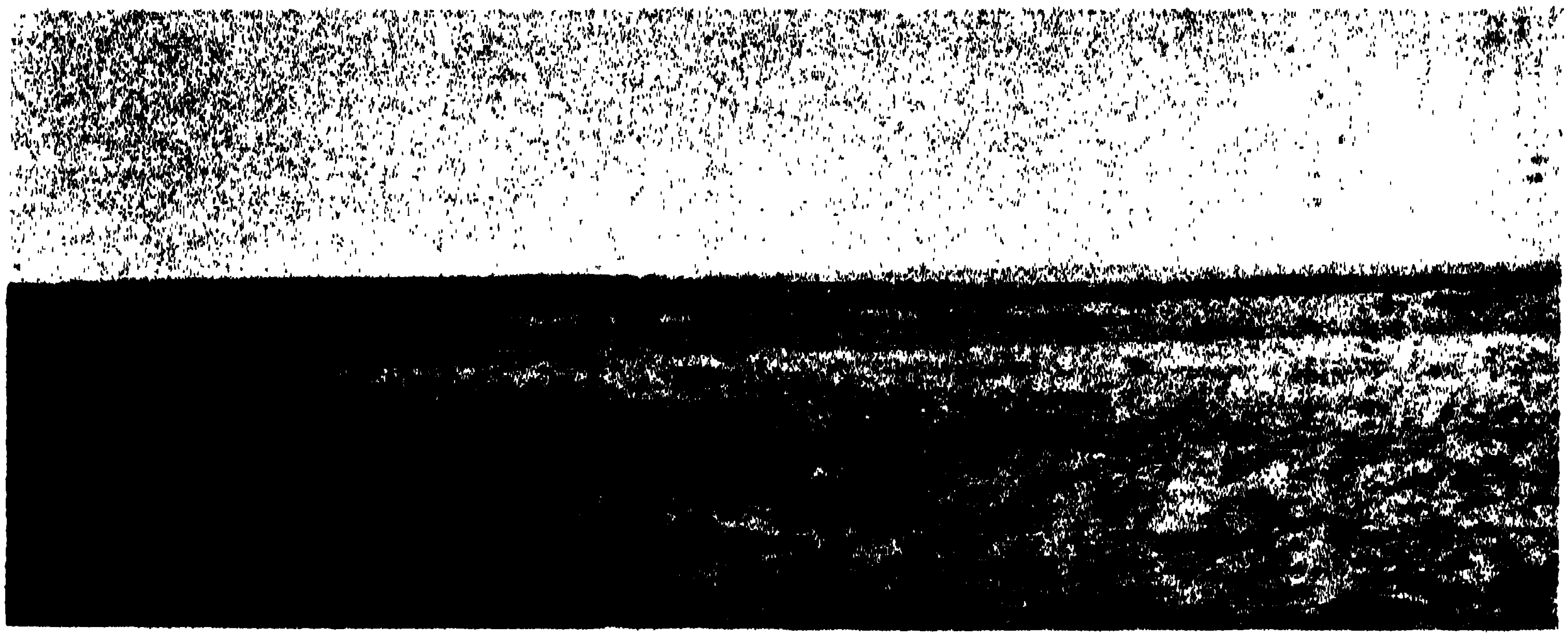
In the vast expanses of the steppes of

central and southern Tunisia one may travel for miles without seeing either towns or villages. The Bedouin tribes that live there are wandering nomads. They migrate north toward the mountains as the advancing summer sears their pastures and south in October or November as occasional rains begin to fall. Their property consists of animals, not of land, but each tribe had grazing rights to certain areas which were recognized by neighboring tribes. Thus their concepts of land tenure was collective and extensive rather than private and intensive. The individual and the tribe had no right in the land as such, merely in the use of it. The official French view was that collective lands were in reality "dead lands," and, according to the decree of January 14, 1901, these nomadic tribes were granted certain rights, but it was pointed out that the state owned these collective lands and could dispose of them as it saw fit. Since that time an attempt has been made to delimit them. Legally the natives were not allowed to make use of the land without permission of the government, but this has not prevented them from living much as before.

In the military territory of the south, by decree of November 23, 1918, the right of the age-old collective use of the land was accorded the nomads—probably as a sop in keeping them pacified so they would act as a buffer against possible encroachment by Italy from the south. It was not till January 23, 1935, that a law was passed with regard to the rest of the collective land. This law made the registering of land the business of the local Caidat, not of the central government, and its object was to "guarantee Tunisians in the peaceful possesion of their lands." Although land might be alienated by an outsider, if those already on it did not register it within a certain

SMALL VILLAGE NEAR GAFSA

DESERT LIFE CENTERS AROUND THE SPRING AIN, WHICH ALSO MEANS "EYE." THE SPRING IS INDEED THE EYE OF THE DESERT.



NOMADS IN CENTRAL TUNISIA ON THE ROAD TO GAFSA
OLIVE PLANTATIONS AND WHEAT FIELDS ENCROACH UPON LAND ON WHICH NOMADS FORMERLY HAD COLLECTIVE GRAZING RIGHTS. NOW THEY MUST PAY FOR GRAZING PRIVILEGES ON STUBBLE FIELDS.

time, still most of this land was fit only to be used as extensive grazing land. Hence the nomads were largely left to live as before, except in central Tunisia. Here Europeans began growing barley and wheat on an extensive scale on land which the nomads had formely grazed over on their trek north. Now they had to pay for grazing privileges—on stubble fields at that—where formerly their herds had grazed for nothing, and it was very difficult for them to understand the reason for this change and to adjust to these new conditions. On their part, the landowners complain that these nomads are the greatest thieves in the world, who take with them when they leave anything which is not nailed down.

Settling the Land

Once the French controlled so much land, actually or potentially, the question was to settle Frenchmen on it. But this was no light task. Algeria was already proving difficult, and the French did not want to arouse another group of natives to hostility. But this lethargy on the part of the government had unfortunate consequences. A few enterprising men or land companies bought up vast domains. Of the 443,000 hectares owned by the French in 1892, 416,000 hectares were owned by 16 individuals[1]—an average of some 60,000 acres apiece. The government made some efforts to remedy this situation. The public Habous and huge Moslem estates were put on the market, and feeble attempts at colonization were made. By 1900 there had been some agricultural progress, but again by a mere handful of Frenchmen. The alarming factor to the government was the influx of Italians, either as laborers or as small farmers. As early as 1881 there were 11,000 Italians in Tunisia as against 708 Frenchmen. In the face of this M. Jules Saurin reiterated that Tunisia could be held only if it were peopled by French peasants. Further attempts at colonization were made from 1900 to 1914. 125,000 hectares of land were sold by the government to new settlers, in lots of 100 hectares or more, and vast blocs of steppe land were distributed. But still there was little immigration of French from the mother country. Most of those who took this land were either already in Tunisia or came from Algeria. And by 1914 even one third of these people had sold their land.

Then came the World War. Many of those who returned were not willing to

[1] Jean Despois, "La Tunisie," p. 140. Paris, 1930.

do all the work necessary to put their properties into shape again; furthermore, in view of the very high prices, the temptation to sell was very great. In this post-war period 80,000 hectares, one seventh of all the land held by the French at that time, changed hands. It was bought by the natives, and, especially in the northeastern part of Tunisia, by the Italians.

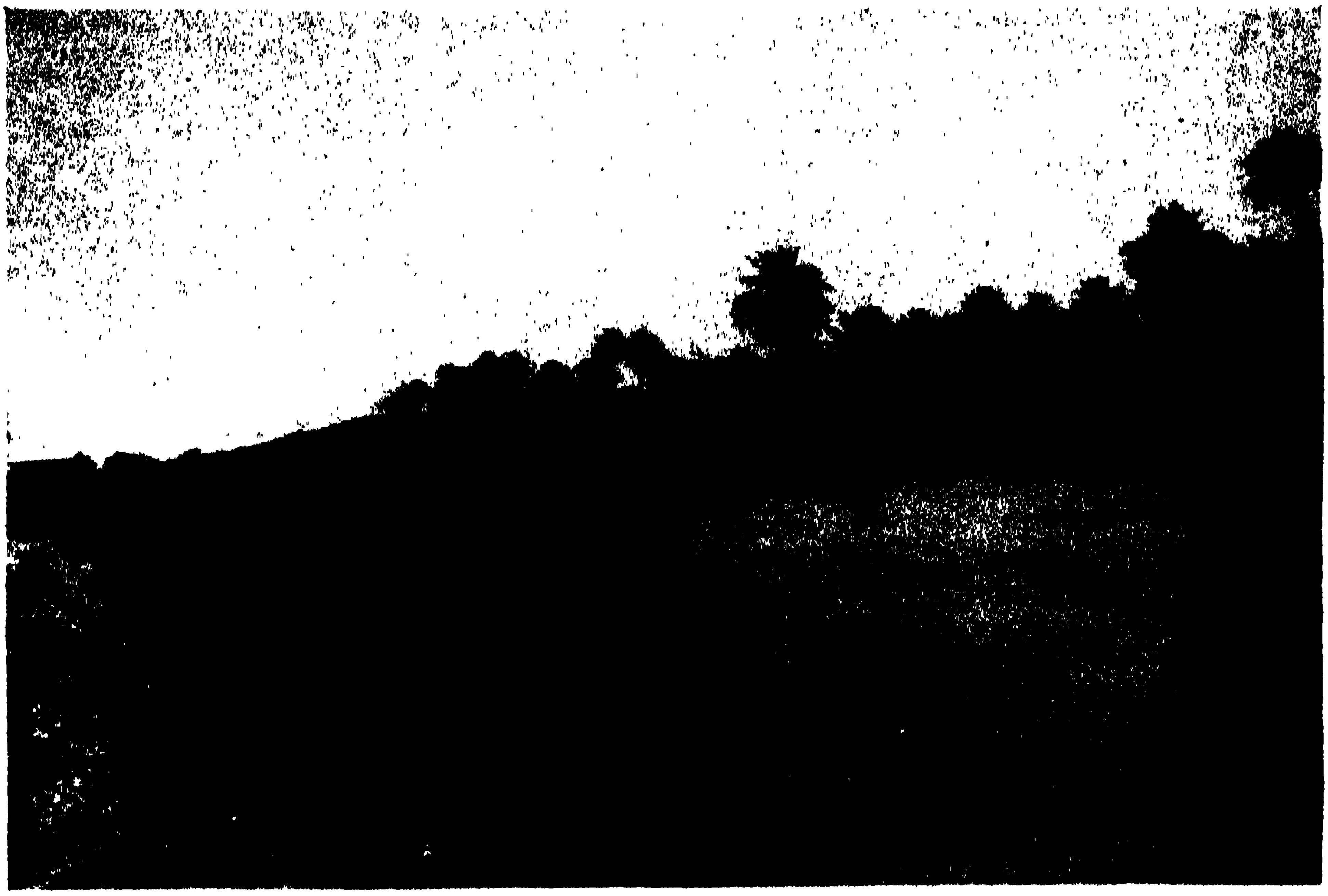
This process of "peaceful penetration" by the Italians in Tunisia merits our attention. The Italian peasant arrived from southern Italy or Sicily without a penny, but he soon found work at 2 francs 50 a day on the large estate of some Frenchman. He worked hard, he lived on very little, and he put aside 40 or 50 francs a month. In 4 or 5 years he had saved a thousand francs or so, and with this he bought a few acres near the farm on which he worked. Thus he could still make a living working for some one else while working on his own land in his spare time. This explains why the large French estates are so often surrounded by tiny plots owned and worked by Italians. At the end of five or six years his own land was producing enough for him to live on and he could spend all his time on it; he had become a land owner in his own right. This miracle can be understood only in the light of the economic and social background of the Italian. In most cases he had come from a large estate which was under the absolute control of the feudal landlord, where misery and malaria were rampant and the standard of living was as low as during the Middle Ages. Tunisia, where he could own his own land by dint of 10 or 15 years' hard labor, was indeed the Promised Land. Furthermore, the Italian government granted long-term loans to its nationals at only 2 per cent. interest.

In view of these circumstances, the French government was faced with the necessity of adopting new methods in order to attract substantial citizens. The recipients of land had to have a certain sum of their own with which to start farming, and they were held strictly to their agreements. The government was disposed to grant credits to really needy farmers, and 33½ million francs were voted to that end. And schemes for further colonization were elaborated.

But in spite of all French efforts toward inducing Frenchmen to settle in Tunisia, they have been slow in doing so, and the number of Italians has increased. The latter are in a majority in Tunis (49,878 against 42,678 French) as well as in Grombalia (3,859 against 1,938), in Beja (1,685 against 790) and at Mateur (1,169 against 398). In the region of Cap Bon, the large range which forms the southern shore of the bay of Tunis and from which can be seen the island of Pantellaria (called by Mussolini the new Mediterranean Gibraltar), the Italians own over 60 per cent. of the vineyards—13,197 hectares against 9,196 in 1921, whereas the number of hectares owned by the French has fallen from 23,379 to 21,156 in the same period. The Italians are also in a majority in the region of the Kef. Furthermore, for the Regency as a whole the percentage of the total French population engaged in agriculture is very low—only 7.7 per cent. in 1926 against 13.6 per cent. for the Italians. Thus the French feel that they are dealing with a kind of economic boring from within.

Wages and Leases

One of the problems that has come up for solution, on land owned by natives, French and Italian, is that of labor supply. Before 1900, and even up to 1914, there was little difficulty in finding enough hands for ordinary unskilled labor on the farms—and wages were very low. The harvest season coincided with the influx of nomads from the south.



THE OASIS OF TOZEUR

Above: EDGE OF OASIS. THE PRESENCE OF WATER MEANS A PROFUSION OF VEGETATION—DATE PALM TREES, OLIVE TREES AND VEGETABLES—INSTEAD OF BLISTERING SAND. OFTEN TWO OR THREE CROPS GROW SIMULTANEOUSLY ON THE SAME PIECE OF GROUND. *Below:* SCENE IN THE OASIS, WHERE THE LAND, INTENSIVELY IRRIGATED AND FARMED, IS OWNED ALMOST EXCLUSIVELY BY NATIVES IN VERY SMALL PLOTS. NOTE IRRIGATION DITCHES ON EACH SIDE OF ROAD.

MARKET SCENE IN TOZEUR

They did not come in great numbers if the harvest of the steppe had been good, but if their own pastures had been ruined by the drought they came in droves to work in the Tell and the Sahel. And once their summer grazing lands were used for the extensive cultivation of cereals it became even more urgent for the nomads to find summer employment. But the area in crop increases each year, on lands owned by natives as well as by Europeans, and many former Bedouins have become sedentary agriculturalists. Coincident with this there has been a building boom in many towns where relatively high wages have been paid. As a result rural laborers have become scarce. This scarcity has made itself felt particularly in the vineyards and olive orchards, where a great deal of the work must be done by hand. The cultivators of cereals have met the labor shortage by resorting to power farming.

Many native landlords have their land worked under the contract known as khammessat. The khammes is a share-cropper who contributes nothing but his work and who receives a fifth (sometimes a fourth) of the crop. He is usually very poor, and the landlord often advances him money for consumers' goods. But a fifth, or even a fourth, of the harvest which is often poor, and sometimes nothing at all, does not make it possible for the share-cropper to repay his landlord very soon. Thus often he becomes tied in debt slavery to the farm for as long as he lives. This system is gradually dying out, and its place is being taken by that of hiring day laborers. But the system of wage laborers has its dangers as well. Under the contract of the khammessat the peasant, who is in reality often a serf, at least must be kept alive through the slack season, so he can work during the next harvest. This is not the case with the wage laborer. Once the harvest is over and he is paid in cash the landlord's responsibility toward him is at an end. He

THE SPRING WHICH FEEDS THE OASIS OF EL HAMMA

goes to the towns and does anything there is to do. But the slack season in the country frequently coincides with the slack season in town, and the laborer is only too likely to become a member of the unemployed proletariat with an extremely low standard of living.

In the olive orchards an arrangement which has proved rather satisfactory to both landlord and tenant is the contract known as the mgharsa. According to the terms of this planting lease or contract a certain area is leased to the mgharsi whose task it is to clear and plant it in olives. The mgharsi furnishes the tools and the young olive trees, and is frequently able to eke out an existence by growing grain between the trees. Furthermore, this cultivation is valuable in providing a tilth which aids in conserving the moisture in the soil. The proprietor may also aid the mgharsi with cash, but these advances have not resulted in the abuses of the khammessat. As soon as the trees begin to bear the mgharsi becomes owner of one half of the plantation. The great olive plantations of the SFAX have been developed to a large extent as a result of this union of European capital and native labor. Very frequently after the division of the plantation the native continues to care for the trees of his former landlord, and he receives for this service, according to the terms of the contract called mougakate, two thirds of the harvest. This arrangement makes rather needless the continued presence of the landlord, who often lives in the neighboring town. But this kind of absentee landlordism is not what the French government is trying to foster. The time may come when it will be difficult to hold areas which have been partly owned and entirely managed by natives for several generations.

French, Italians, Natives

It has been a difficult task indeed to colonize Frenchmen in Tunisia. In the

north the Italians, with their low standard of living and their expert ability at raising grapes and making wine, have been able to become small landowners at the expense of the great estates of the French. In central and southern Tunisia the native, with a standard of living still lower than that of the immigrant from Italy, has succeeded in keeping the growing of cereals and of olives largely in his hands—even if the land is often owned by the French. And in the oases the native not only does the work but he owns the land—with but few exceptions. As a matter of fact division of property has gone so far in certain instances that different branches of an olive tree may belong to different people. But the net result is that the land of Tunisia is being legally divided up by natives and Italians, but not by Frenchmen.

Italians comprise over 60 per cent. of the wine growers in Tunisia, they own more than half the area planted in grapes, and they produce more than half the wine. The 77,000 hectares owned by the Italians are a part of the most intensively cultivated land in the Regency, whereas much of the 650,000 hectares owned by the French are in the areas of more extensive cultivation in central and southern Tunisia. Thus a kind of state within a state has been in process of gradual evolution. But this Italian state within a French Protectorate has as its very secure base the land. It is the very stability of this Italian state which alarms the French, who point out that this peaceful penetration of Tunisia by the Italians has been made possible by French control and the security concomitant with it as well as by the capital investments of the French. But the French are realists. They know that the Protectorate can be held only if sufficient people are loyal to France. If non-Frenchmen own great areas of land in small plots they will tend to form a bloc, the loyalty of which to France can with difficulty be expected. The problem becomes not unlike that which confronted Californians with reference to the Japanese. The French do not relish the prospect of having to administer a colony of natives and Italians, with only a handful of Frenchmen—and having to pay for the administration.

This problem has given the French colonial administrators many headaches and sleepless nights. The increase of Frenchmen living in Tunisia is only about 1,000 per year, and of the total 71,000 French registered in 1926, more than 11,000 were naturalized foreigners. The Maltese, naturalized under the Franco-British agreement of 1923, became citizens automatically unless they individually elected to remain British. They numbered 13,500 in 1921, but only 8,400 in 1925, which indicates a rather rapid "assimilation." An act of December, 1923, imperiled the nationality of the 130,000 Italians living there at the time. Under this act, vigorously protested by Rome, it was necessary for the Italians to renew their nationality or automatically become French citizens. This act was suspended for three months, and the suspension repeatedly renewed till 1935. This insecurity kept the Italians in a state of tension instead of definitely settling their problem. Then came the settlement of 1935. All persons who shall be born in Tunisia of Italian parents until 1965 are to have Italian nationality, except that those who are born between 1945 and 1965 may at their option assume French nationality at the time they attain their majority. As early as 1931 the majority of the Italians was apparently checked, "as they then numbered 91,178, and the French, 91,437, the slight excess indicating some success for French policy, or at least for the census officials."[2]

The French policy of assimilation has

[2] Herbert Ingram Priestly, "France Overseas," p. 192. New York: Appleton & Company, 1938.

THE OASIS OF EL HAMMA

Above: DUNE ENTERING THE OASIS. *Below:* EDGE OF OASIS. THE TRENCHES AND WICKER FENCES ARE CONSTRUCTED TO KEEP SAND FROM DRIFTING IN.

been countered by Italian Fascist propaganda which has literally flooded the Regency. But this propaganda may overreach itself, as it did last January, 1939, after the speech by Daladier in which he pointed out that not one foot of territory of the French Empire would be ceded away, "that there is no law against the right of France." (*Il n'y a pas de droit contre le droit de la France.*) Vituperation struck a new low in an article of *Tevere*, under the caption "Spit on France." Even many of the Italians were amazed, and found it hard to believe that their country could sanction such journalism. And the result was a big surprise to both French and Italians. In a short time some 5,000 requests to become naturalized French citizens were received by civil authorities. And February 15 a new paper, *Il Giornale*, friendly to France, began to appear in Tunis.

The exploitation of any "backward" country by a "progressive" one means the juxtaposition of peoples with entirely different backgrounds. Friction is apt to be more severe in town than in the country. The French have interfered as little as possible with the urban natives in their trade, handicrafts and customs generally. There seems to be less conflict—open and latent—between French and natives than between Italians and French. The latter have all the good government jobs, they own the mines, the great estates, the railroads and buses, thriving businesses, the chic restaurants. But the tens of thousands of Italians in Tunisia patronize Italian business men whenever possible. The French and Italians mix little, and because of the tension each group emphasizes its loyalty to its mother country. There is a plane of cleavage between the French who own the large estates and the small Italian landowners, but there is what almost amounts to a No Man's Land between the French and Italians who live in towns. This problem can not be more than mentioned in a short paper. Suffice it to say that the cloc or "cyst" of Italians, quite large and firmly knit, could very well act as a Trojan horse in case of open conflict between France and Italy.

Then there is the question of the native. Without a doubt, the productive capacity of Tunisia has increased greatly since it has been in the hands of the French. They have built railroads, hundreds of miles of magnificent highways, many schools and hospitals, bridges, public buildings and, not to be overlooked, huge barracks. The Regency exports great quantities of agricultural produce—olive oil, wheat, barley and wine, as well as minerals such as iron ore and phosphate. Certainly such a development would not have been possible, or at least not for a long time, under the old capricious arbitrary native régime, the taxes of which were burdensome in the extreme. Of these there were very many: the mejba—a poll tax, first established in 1856 which, when augmented in 1863, was the cause of bloody uprisings. There was a tithe on cereal crops which was based on Koranci law and was payable in kind or in money. There was also a tithe on oils, imposed since 1730, and in the daidats of Cap Bon and SFAX, the mradjas—a tax on fruit and vegetables. The native government could never establish its budget in advance because it was impossible to "foretell the amount of resistance which the taxpayers might offer." Indeed, the government was described as "an arbitrary government tempered by insurrection."

The French have changed all this. But has the standard of living of the native been materially raised? Certainly not at all in the same proportion as the productive capacity of the country has been increased. Many great estates export hundreds of tons of grain, which

is produced by the most up-to-date equipment. Yet hordes of natives on the verge of starvation add a few more pounds of cereals to their larders by gleaning in the fields owned by foreigners. It would seem that too little attention has been paid to the living conditions of the natives—they were not even numbered; in the census of 1931 they numbered 2,215,000. But they object that although they help pay for and build railroads, for instance, they have no money with which to buy tickets on the trains. Nor can they get too loud in demanding liberty, equality and fraternity. The French should never forget that Mussolini is the self-styled Defender of the Moslems.

In spite of all the attempts at colonization in Tunisia, French colonists lag. France sends in more money than men, with the result that large estates are still operated by capitalists. The Franco-Tunisian Company, which operates the Enfida, employs 100,000 natives, few Europeans. One third of the foreign-used land is controlled by companies. But the small owners who work their own farms are not French, and, as has been shown, their number is increasing. There is much truth, especially in a dry area like Tunisia, in the statement to the effect that "le meilleur Resident General c'est la pluie," but in the long run the race which sticks close to the soil will probably be in possession of the country. As long as the principle of nationality is invoked, as long as the rulers of nations, like simple peasants, believe in "rounding out their domaines," just so long will the Italians clamor for administration from Italy; and as long as the natives realize that the export of great quantities of foodstuffs and minerals does not coincide with any appreciable increase in their standard of living, just so long will they clamor for self-determination. It is to be hoped that the traditional liberalism of the French will emerge triumphant in their dealings with both Italians and natives. If not—if the natives are not allowed to voice their natural and national aspirations they will be somewhat justified in saying of the French what Calcagus, the leader of the Britons, is reported to have said of the Romans: *Auferre trucidare rapere falsis nominibus imperium, atque ubi solitudinem faciunt, pacem apellant.* (To plunder, to slaughter, to steal, these things they misname empire; and where they make a desert, they call it peace.)—Tacitus, "Agricola," Sec. 30.

A program of concessions to the natives and "appeasement" for the Italians should be motivated by a sense of justice and good-will on the part of the French. If such a program be inaugurated after France has been weakened by the war it will have no moral value. It would only succeed in convincing both natives and Italians that they could and should make greater demands. These the French would, to save face, refuse to grant. All parties might consider the others to be in an untenable position and war or revolution might be the result. The strength of continental France is in a peasantry firmly rooted to the soil, but as has been seen the French in Tunisia have grown only adventitious roots. Only careful diplomacy can prevent the Italians in Tunisia from playing a rôle similar to that played by the Germans in Sudetenland.

VITAMINS AND SENESCENCE

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VITAMINS have lost their mystery so for as their chemical composition is concerned but still retain some cloak of anonymity so far as their *modus operandi* goes. Instead of A, B, C and D we now have carotene, thiamin, ascorbic acid, calciferol and in addition a large and growing flock of B vitamins besides the original or B_1 (now called thiamin). Likewise at least two other fat-soluble factors are known, E or alpha tocopherol and K, a group of naphtha-quinone derivatives. It is no longer *de rigeur* in our best nutrition circles to fall back on the alphabet in designating the vitamins but instead the proper chemical names of these substances are used. This is quite in line with the polite usage of proper names of individuals when the identities are known instead of numbers and letters which might be used when they were still unknown.

THE B VITAMINS

The B vitamins are grouped together because at one time, until 1919 at least, they were thought to be one substance only, antineuritic or antiberiberi in character. Of course this substance, thiamin (B_1), is only one, although perhaps the most overwhelming in the effects exerted by its deficiency, of a group of at least six and possibly eight or ten equally indispensable vitamins. The first of this family of B's to be detached after thiamin (synthesized 1932)[1] was designated G by Goldberger and by Sherman, B_2 by the British workers. This turned out to be riboflavin, identified by Kuhn in 1934. It is the chief B vitamin contained in milk and probably in green leaves.

The next separation was that of vitamin B_6, named by P. György in 1935, now called pyridoxin or adermin, synthesized in 1938. All three of these factors, thiamin, riboflavin and pyridoxin, can be rather readily removed from water solutions of vitamin rich foods such as yeast, liver and rice bran by shaking such solutions with fuller's earth. In 1936 it was pointed out by Koehn and Elvehjem of Wisconsin, and Lepkovsky and Jukes of California, that after such removal there remained in the filtrate something which was necessary for both chicks and rats, in addition to the three absorbed B vitamins. This became known as the "filtrate factor or fraction." But by 1938 the identity of still another B vitamin was discovered, nicotinic acid, thought to be the chief substance lacking in the diets which produce pellagra.

THE "FILTRATE FACTOR" DEFICIENCY SYMPTOMS

Now crystalline chemically pure thiamin, riboflavin, pyridoxin and nicotinic acid were available and in this laboratory and elsewhere these with necessary fat-soluble vitamins and a purified basal diet were fed to young rats. After six to eight weeks most of these rats which happened to be black coated began to show silvery gray patterns in the fur. Their growth was impeded and after a few weeks skin eruptions occurred and in most cases their lives came to an end within six to eight months. They took on all the appearance of extremely aged

[1] For an interesting description of this subject see R. R. Williams and T. D. Spies, "Vitamin B_1." Macmillan Company, 1938.

By courtesy of Journal of Nutrition.

FIG. 1. THE EFFECT OF VITAMIN B ON A RAT FAMILY

NUMBER 2 WAS GIVEN ALL THE B VITAMINS THROUGHOUT THE EXPERIMENT. NUMBERS 1, 3 AND 4 WERE FED THE ANTI-GRAY VITAMIN DEFICIENT DIETS.

animals with loose wrinkled skin, sparse silvery hair, emaciation and sometimes severe and persistent skin ulcers at the base of the tail and on the hind legs and feet. If concentrated extracts of the "filtrate factor" were given them at any stage of the deficiency their condition improved at once with full return to health and color of fur. A photograph of gray and cured rats is shown in Fig. 1 and of a senile-appearing deficient rat in Fig. 2.

THE GLANDS INVOLVED

Microscopic study of the organs of these rats has shown that the deficiency caused consistent damage to the adrenal glands, thyroids and sex glands and that on recovery the damage was repaired, although evidences of it were left.

It is not clear whether the primary damage occurred in the adrenal cortex or somewhere else, perhaps in the anterior pituitary gland. The latter gland is thought to be the "motor" or master control of several other endocrine organs, notably the gonads, the thyroid and the adrenals. If any of the functions of the anterior hypophysis therefore are destroyed or altered by the vitamin deficiency subsequent changes in the thyroid, adrenal cortex and sex glands may be expected. Thus the depigmentation of the hair may occur through the intermediation of either or both thyroids and adrenals. Administration of thyroid and adrenal cortical extracts has produced slow darkening of the grayed fur of vitamin-deficient rats but has not benefited the animals otherwise. This leads to the suspicion that the deficiency produced poor functioning of these

glands as only one of its far-reaching effects.

The young silver foxes later mentioned as filtrate factor deficient were found on autopsy to have enlarged red-pigmented thymuses as well as evidence of previous but largely repaired damage to the adrenals. It has been reported frequently that victims of Addison's disease, due to destruction of the adrenal cortex, have enlarged and sometimes regenerated thymuses.

When normal stock female rats were given the deficient diet on the day their young were born nearly complete failure of lactation resulted. Deficiency in one or more of the other B vitamins had no such devastating effect. If the endocrine system is affected by the deficiency it is not surprising that lactation should fail since anterior pituitary hormone control of this function is known to exist. Mediation or direct action in initiation of lactation by the adrenal cortical secretion is also generally recognized.

Experiments were made with cocker spaniels placed at six weeks of age on the purified and filtrate factor deficient diet and with results similar to those seen in the rats. The coal-black long curly hair of these pups after two or three months turned gray at the roots and gradually grew out gray in color. One was cured by administering a "filtrate" made from yeast with almost immediate new growth of black fur and increase in weight. A similar diet fed to six young silver foxes, three with and three without "filtrate factor," resulted in the sudden death of one of the deficient animals within seven weeks. The other two were given the missing factor at once to save their lives, but they lost their fur almost completely. Soon a new coat of fur grew in but with white instead of black under fur. They all grew well. One of the controls and one of the gray pelts was made up into a neck piece as a reminder of this experiment.

Is Pantothenic Acid Involved?

Meanwhile the "filtrate factor" origi-

FIG. 2. A VITAMIN DEFICIENT SENESCENT RAT
FIVE MONTHS OLD. NOTE THE GRAYING OF HAIR, LOSS OF HAIR AND WRINKLING OF SKIN.

nally postulated by Lepkovsky and Jukes and Elvehjem and Koehn as necessary for chicks has been identified with the pantothenic acid so long studied by R. J. Williams. This acid has now been synthesized and is becoming available in crystalline form for feeding experiments. Is it or is it not the same thing as the anti-gray hair factor in the filtrate? No complete answer is yet available, but it can be stated confidently that pantothenic acid is concerned in the graying phenomenon, although it is probably not the only factor involved. It is now being fed to rats and dogs both with and without the crude "filtrate factor." Darkening of the gray fur has occurred at least temporarily after some delay when sufficient amounts of pantothenic acid were given.

A rather surprising interrelation between the anti-gray hair vitamin deficiency (which in our early experiments involved pantothenic acid deficiency as well) and nicotinic acid intake has been seen in the dogs. It was assumed that nicotinic acid is essential for the prevention of "black tongue," the canine analogue of pellagra, and that dogs deprived of this substance would exhibit early failure of nutrition. But the animals reared on purified basal diet plus the crystalline vitamin supplements, thiamin, riboflavin and pyridoxin, grew normally and except for gradual and complete depigmentation of the fur and occasional diarrhea appeared to be in good health. One male cocker spaniel remained well except for a dust-mop gray coat instead of his natural glossy black hair after sixteen months on this régime. There were no signs of black tongue at any time. His photograph with a normal control is shown in Fig. 3. But his sister which had received the same diet plus nicotinic acid, lost hair color, appetite and weight after only four months and when apparently about to die was given the "filtrate factor" preparation. She rapidly recovered normal health with normal coat color. The same rapid failure was seen in several other young dogs and also in rats when nicotinic acid was added to the "filtrate factor" deficient diet. Perhaps the anti-gray hair vitamin, nicotinic acid and pantothenic acid participate in the same cycle of tissue reactions, balanced nicely so that omission of one topples the structure but omission of all is less harmful.

A curious phenomenon is seen in the continued growth and youthful appearance of rats fed the usual diet plus yeast and fat-soluble vitamins and an additional daily supplement of yeast filtrate. At two years of age, when stock rats begin to fall off in weight and show signs of failure, these animals are sexually active and of near-giant size, the males being 500 to 700 grams in weight as compared with the normal 350 grams. Some scattered graying occurs in their fur but no general depigmentation. The appetite and efficiency of intestinal absorption are maintained at the level of young adults. One of these super-developed rats along with a normal brother of the same age, twenty months, is shown in Fig. 4. These large animals are sexually mature and physically active, in contrast with the young giant rats produced by anterior pituitary gland transplants by P. E. Smith a few years ago.

Where Do We Find These "Filtrate Factors"?

So far little progress has been made in the assay of natural foods for the "filtrate factors." Certainly the anti-gray hair fraction is distributed somewhat sparsely in such foods as have been tried thus far. One may be led to speculate as to whether it was originally provided for man as for other animals in the bran, twigs, viscera, insects and other foods now considered inedible. Plantation cane molasses, for instance, has been

FIG. 3. TWO COCKER SPANIELS

FED EXACTLY ALIKE FROM WEANING, EXCEPT THAT THE GRAY DOG (ORIGINALLY BLACK) IN THE FOREGROUND LACKED THE FILTRATE FRACTION OF THE B VITAMINS.

found well endowed with this fraction, but refinery molasses and the crystalline sugars are free from it. Whole wheat and wheat bran (but not to the same degree, wheat germ) contain it but refined flour lacks it. Canning has an adverse effect on the filtrate fraction of the B vitamins and leaching during cooking in water or steam removes it from the cooked food.

A cheap and effective source of all the B vitamins now known might be made up of black strap cane molasses and wheat germ or even wheat bran. Such a mixture is actually in use as a tonic and medicament in at least one student hospital and apparently with satisfactory results. This is a commentary on the remarkable cycle accomplished by industry and science in our food supply, in which we carefully remove the vitamin-rich part of the natural foods, then prescribe the removed offal as medicine! When the removed vitamins are prescribed in the form of pure extracts or synthetic products the whole process becomes ludicrously expensive.

Thus apparently all the processes which civilization has imposed upon our foods tend to remove or destroy whatever part of this fraction is present in the materials which we now regard as fit for human use. The remedy should probably be sought not in the return to primitive feeding habits but in the isolation, identification and thorough study of these as of the other vitamins and the inclusion of suitable sources in the diet.

Of course many prematurely gray people have written to inquire whether there is any reason to suppose that the vitamin will affect their hair color. Some who have tried taking rice bran and yeast concentrates faithfully have reported that the new hair is growing in dark instead of gray. The process is necessarily slow, since hair once gray can not be expected to change color and no one wishes to remove all gray hair and wait for the slow appearance of the new hair of another color! However, if an arrest of the graying process can be obtained this will satisfy many people.

But the more important phase of the application of these findings to humans lies in the possible bearing they may

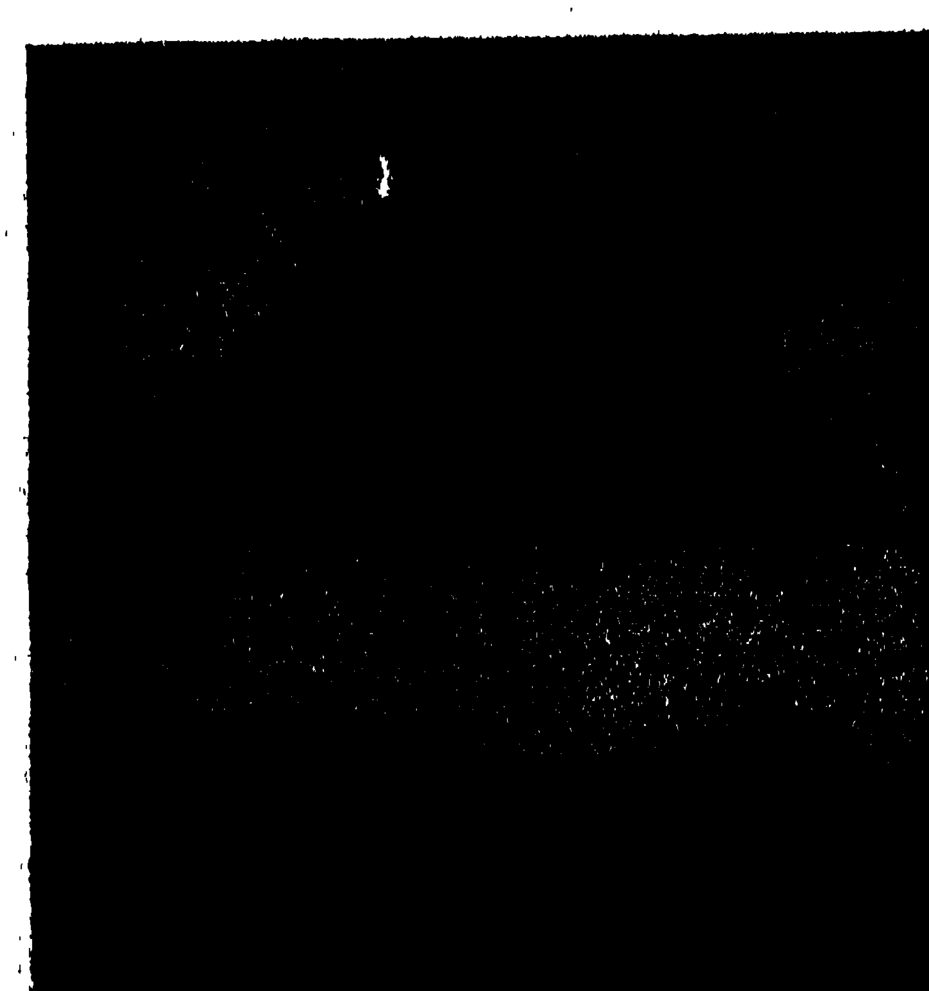

FIG. 4. LITTERMATE BROTHERS

TWENTY MONTHS OLD, FED ALIKE EXCEPT THAT THE LARGER RAT RECEIVED AN EXTRA SUPPLEMENT OF "FILTRATE FACTOR" CONCENTRATE.

have on the prevention of premature aging. Are the adrenals, thyroids and other glands made relatively inactive by diet deficiency and are some of the phenomena of old age the result of such inactivity?[2] Are there long-continued slight vitamin deficiencies which bring about the premature graying and the metabolic and other disorders of senescence? Old age phenomena can doubtless not be deferred indefinitely, but modern living seems to bring them on earlier than need be. Perhaps primitive man obtained more of all the necessary food factors from the unrefined whole plants and animals on which he subsisted than we can get from our refined, milled and cooked dainty fare.

[2] See A. J. Carlson's delightful chapter on the endocrines in "Problems of Aging, Biological and Medical Aspects," edited by E. V. Cowdry, Williams and Wilkins Company, 1939.

In any case if a true interrelation of a vitamin and the endocrine system has been uncovered new means of both experimentation and clinical use of vitamins will result. Some of the treasured mystery of the functioning of both these groups of potent substances may be eliminated.

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WHEELS

I HAVE always been interested in the relationship of the wheel to the advance of civilization and the rise of man from the state of savagery. There has been a good deal of exploration as to where the wheel was discovered and how it first was used. It is suggested that it came from putting logs under heavy objects to roll them about, and then gradually went on to more refined uses, from transporting of objects and men to more creative or manufacturing uses, such as in the potter's wheel, the spinning wheel and the mill wheel. Our own early American life and our spread across this continent owed much to the wheel, and it now plays a predominant role in our economic structure.

We know that the Eskimos have been able to build up a fairly satisfactory culture without the use of the wheel; what they do, though, is of a very simple character, and their snowy environment has not been conducive to the use of wheels. But upon nearly every civilization of the world wheels have had a profound influence. Few of us pause to realize the power of wheels in our daily life, whirling about us everywhere in the civilization which they have played such a large part in creating. Literally, "Wheels That Make the World Go Round," and "Wheels within Wheels." Not just the obvious wheels we all see rolling under us on trains, automobiles or bicycles. There are the tiny wheels tucked away in watches to tyrannize over us in the matter of time. There are the wheels in typewriters and presses, in engines and machines and other devices about us everywhere. Steamships, airplanes, the tractor and the armored tank alike are impotent without them. Wheels have done much in building up and bringing together man's world; misused, they can the more rapidly destroy it.

Perhaps the most significant effect of the development of the wheel was that it gave mobility to man and increased his range of activities. This mobility has been vastly increased by the steam and now the gas engine in conjunction with wheels, tracks, roads or water. Wheels mean movement. Movement means danger, unless that movement is controlled. Wheels have made possible a military attack which is unprecedented and which, as we have recently watched it develop on this earth, may bring revolutionary changes in all human affairs.—*Ray Lyman Wilbur in School and Society.*

SOIL DYNAMICS

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THE surface of the earth is a field in which mineralogy, biology, physics and chemistry cross and recross their paths, collectively working for the creation of the peculiar epidermis of the land which is known to us as soil.

The soil is not merely a heterogeneous mass of different products of disintegration and decomposition of rocks and not just dirt from which plants can grow. It is a harmoniously organized dynamic system minutely coordinated with its environment including geological history, climate, relief and biological pressure. It is said that any normal soil is in equilibrium with its environment. Such an equilibrium or "steady state," however, is not a state of static rest as might appear to a casual observer: it is a state of continuous readjustment to the ever-changing environmental factors such as climatic conditions, biological activity and erosion. The equilibrium between the soil and its environment does not spring into being spontaneously but evolves gradually through an intricate pedogenic (soil-forming) process which consists of various physical and chemical changes of the original material.

Reaching an equilibrium does not indicate the end of the soil-forming process. This process never ends as long as the soil exists; when it ends the soil dies, becoming a relic or fossil, and ceases to be a dynamic body.

The continuity of the pedogenic process does not contradict the equilibrium between the soil and its environment. The fundamental characteristic of the pedogenic processes is their cyclicity. In this respect they differ from the concurrent geological processes which can be regarded as straight-line processes. The latter begin, develop and end at some static stage at which their products may rest unchanged for a full duration of geological ages. The best illustration of such a difference is the formation of soil humus and of various organogenic geological deposits such as coal, mineral oil, peat and petrified wood.

Every soil contains certain amounts of humus ranging from a fraction of one per cent. to as much as about 20 per cent. according to the type of soil and degree of its biological pressure. The content of humus is relatively constant in every soil adjusted to its environment. The amount of humus is constant but humus itself is not everlasting; it renovates itself continuously. Continuously certain parts of it decomposes into the simple end products such as water, carbon dioxide and mineral salts and simultaneously an equal amount of it is formed anew from the organic residues. The radiant energy captured in organic compounds is turned over to humus and released during its decomposition. Every molecule of soil humus is in a permanent state of transformation. Every quantum of its energy is in a slow but ceaseless motion. The matter and energy which yesterday were a part of living organisms are in soil humus to-day and will be released to-morrow in the form of elemental constituents ready to be resynthesized and utilized by the next generation of organisms. These migrations of matter and energy develop in cycles.

The same organic residues give rise to the organic geological deposits, peats, oils, coals, but the process of their transformation is fundamentally different. The residues do not decompose into the simple end products and do not liberate

their energy. They undergo sterilization, carbonation or petrification and pass into a static stage of conservation. Their potential energy becomes dormant and may rest as such for the duration of the geological eras. Unlike the carbon of humus the carbon of coal does not disseminate as carbon dioxide ready for the photosynthesis of the carbohydrates of plants. The migration of matter and energy from living bodies to the geological formations proceeds along a straight line. When it reaches the static state, it ends in rest.

Cyclicity of the soil-forming processes in so far as matter is concerned can be demonstrated in many ways. The cycles of carbon, water, nitrogen, sulfur, phosphorus and so forth are well known. The cycles of energy, however, are not as yet sufficiently clear.

The immediate sources of energy involved in the pedogenic cycles are cosmic, especially the radiant energy of the sun and a potential energy of crystallization concealed in atoms, molecules and crystals of minerals. Applying the terms of geochemistry to geophysics, these forms of energy may be distinguished as the vadose (of superficial origin) and juvenile (deep seated, issued from deep within the earth) energy of the pedogenesis.

The vadose energy is introduced into cycles through a photosynthesis of plants, the equation of which is:

$$6CO_2 + 6H_2O + 677.2\ \mathrm{Cal} = C_6H_{12}O_6 + 6O_2$$

and by numerous endothermic reactions which take place in the soil itself.

Juvenile energy is liberated by the weathering of rocks through a decomposition of minerals. The bulk of rocks is composed of alumosilicates. Alumosilicates are endothermic compounds which were formed by crystallization of magmas under conditions of high temperature and high pressure. The decomposition of these minerals on the surface of the earth is accompanied by an emanation of heat. Clayization of one gram of granitic rock liberates about 120 calories.

The soil is a medium in which vadose energy and juvenile energy merge and pass through intricate channels of the soil-forming reactions.

Obviously the pedogenic cycles do not develop entirely within the physical media of the soil. Certain segments of them pass through the biosphere. Matter and energy leave the soil for living bodies and return to it in the substance of humus. Naturally only the segments of cycles which pass through the soil are of primary interest to soil science. The others belong to the closely related disciplines of biophysics and biochemistry.

As the epidermis of the earth, the soils are naturally subject to a general geological weathering. Consequently, in the soil the strictly pedogenic cyclic processes are intimately combined with the straight-line geological processes. In fact the latter constitute an essential part of soil dynamics. Cyclicity of migration of matter and energy through the soil and life does not indicate that the same atoms of matter and the same quanta of energy continuously travel from the soil into the biosphere and back into the soil. Certain and probably large quantities of both matter and energy continuously leave the cycles, being disseminated in the atmosphere, removed from the soil by leaching for ultimate concentration in the universal ocean, or statically fixed in compounds stable in a thermodynamic environment of pedogenesis. An equilibrium, however, can not suffer any losses, because any loss would immediately disturb the balance. The losses are covered by equivalent amounts of new materials and by new energy which become involved in the rotation partly by living organisms from the cosmos and partly by decomposition of the rocks which release elements and potential energy from the clasps of petrification.

In the soil which is in dynamic equilibrium with its environment the pedogenic cycles are precisely adjusted to the concurrent geological processes so that losses and gains of both matter and energy are continuously and remarkably balanced.

The pedogenic process takes place in the medium designated as the soil body which is a layer on the surface of the earth affected and reorganized by this process. The thickness of such a layer ranges from just a few inches to several feet; in a relatively few instances it exceeds ten feet. The average thickness of various soils depends upon the type of climate and vegetation which are instrumental in development of these soils, upon the nature of rocks, upon the relief of the land surface and upon the soil's own age.

Every soil body consists of several soil horizons. A soil horizon is a part of the soil which develops its individual physical and chemical characteristics, due to a concentration in this part of body of some particular reactions of the pedogenic process. It can be a local intensification of hydrolysis; of oxidation of certain compounds; of solution or coagulation and precipitation leading to an accumulation of various salts, colloidal materials or humus. The reactions which take place in different horizons may be predominantly exothermic or endothermic. In the development of some horizons the release of vadose energy may be the main factor whereas the development of the others may depend chiefly upon liberation of juvenile energy. In some horizons kinetic energy undergoes fixation whereas in the others potential energy is put to work. Due to these differences each genetic horizon of the soil acquires an individual chemical character as well as an individual thermodynamic coefficient. All horizons of the soil body considered in their natural sequence from the surface downward constitute collectively a soil profile.

A fundamental feature of the true soil horizons is a genetic relationship between all horizons of any given profile. All horizons of the profile develop in unison, simultaneously and usually from essentially the same original material. Their dissimilarities, physical or chemical, no matter how great they may be, are due entirely to the harmonious changes of the original parent material. A development of any one horizon is a necessary accompaniment for the development of the other horizons in the profile.

An equilibrium of the entire system presupposes the equilibria of all its integral parts. Consequently the normal horizons do not grow indefinitely after they reach the stage of equilibrium with the environment. The old rather philosophical concept that the soil evolves, develops, grows old and finally deteriorates has not been based on facts. Soil indeed may change its character, but it changes according to the modifications of the environment. Otherwise it remains constant.

It is true, however, that in some particular instances the straight-line geological processes which may take place in the media of the soil profile are strong enough to dominate the strictly pedogenic activity in the soil. They may lead to the actual growth of certain characteristics. An illustration of this is the formation of certain static products which are stable in the existing thermodynamic environment of the soil; for example, the petrified hardpans. The petrification of the hardpans might develop as a by-product of pedogenesis. Because of the stability of the hardpan in its thermodynamic environment its formation terminates the migration of matter and energy in the zone paralyzed by petrification. Such a hardpan can be regarded as a soil horizon affected by a sclerosis. It may grow and in some instances may ruin the original soil.

There is a fundamental difference between the soil horizons and mechanical layers of stratified parent materials. In many instances a soil develops from parent material composed of several strata differing from each other. Each of these strata might have been formed at different times, by different agencies and from different materials. A thin veneer of loess or wind-blown sand may be deposited upon glacial till; a mantle of deluvial assorted drift may be deposited upon the residual detritus or upon the same loess; strata of coarse gravelly alluvium deposited by the swift current may be interbedded with the silty or clayey alluvium settled from the slowly moving water. Each of such layers accumulates above the other at different times; one might be formed by ice, another by water and the third by wind. One might be formed from a nearby source of material and another transported from a great distance. Each layer can differ from the other, physically and chemically, but individual properties of any one of them have no relationship to those of the other layers.

In many instances such layers are so thin that an evolution of the soil profile embraces several layers. In such instances different genetic soil horizons or certain parts of them might develop from the originally dissimilar parent materials so that differences between horizons which develop due to the evolution of soil profile might be superposed upon the differences of the original materials. The individual features of the soil horizons which develop due to a pedogenic process are distinguished as the *acquired* characteristics and are contrasted to the *inherited* ones which are due to the nature of the original material.

The soil as a whole is an unconsolidated porous body. It consists of the three phases: solid, liquid and gaseous. The solid phase forms a mechanical framework or a skeleton of the soil body. It consists of the more or less loosely connected fragments of rocks and minerals and various products of their decomposition. These primary units range in size from the ultramicroscopical colloidal particles to grains of considerable size.

The fundamental physical property of the soil is its texture. The term *soil texture* connotes the effect of its mechanical composition, that is its arrangement from particles of various sizes taken in certain proportion to each other and mixed indiscriminately into a more or less uniform mass. The primary particles, or mechanical units of the soil material, are produced by a physical disintegration of rocks and their chemical decomposition, the mechanical composition of this material, however, in many instances is the product of an assortment and redeposition of the primary units by water, ice or wind.

Closely related to the texture is *a soil porosity* which represents a ratio between the solid and other phases of the soil body. The pore space forms a system of interconnected voids and vessels through which pass the flow of soil solutions and gases, therefore, a qualitative aspect of soil porosity, that is a pattern of distribution of the pore space throughout the soil body has a particular significance for soil dynamics. The same or very similar porosity of the soils of different textures might have a fundamentally different pattern. The ratio of capillary to noncapillary porosity is especially important because of its bearing on velocity of circulation through the soil of its mobile components.

To a considerable extent the texture and porosity determine a *soil consistence.* The soil consistence depends upon the mechanical composition of the material as well as upon an arrangement of the mechanical units in regard to each other which relates directly to the pattern of the pore space in the soil. Unlike soil texture, soil consistence represents a con-

dition of the soil material rather than its constant characteristic. It is subject to changes according to the moisture conditions. Certain amounts of water absorbed by the soil give to it a degree of plasticity and viscosity. The grades of plasticity range from a maximum in the soil of the finest texture to a vanishing point in the soils of the coarsest texture. The grade of friability, or of a lack of an adhesion among the primary particles, ranges in an opposite direction. Plasticity, viscosity, friability are the examples of various forms of the soil consistence.

Finally, soil science attaches much significance to the *soil structure* which represents an arrangement of the primary particles of soil material into various aggregates. A development of structure fundamentally changes the qualitative aspects of soil porosity because of the formation of comparatively large voids between the aggregates. Like a consistence, soil structure refers to a condition of soil material rather than to its permanent property. It also is subject to changes according to the moisture condition. Usually soil structure is expressed best in the air dry soil. An increase of moisture tends to decrease stability of the aggregates and to reduce the structure of soil material to a vanishing point.

Texture, porosity, consistence and structure together with color are the most striking physical characteristics in which the genetic soil horizons differ from each other. The normal soil develops from parent material which in a broad sense is more or less uniform as regards its color, texture, porosity and consistence. Various modifications of these properties in different parts of the soil body reveal the story of soil genesis without an understanding of which soil dynamics can not be fully understood. Such changes are neither exclusively physical nor exclusively chemical. Soil physics and soil chemistry work hand-in-hand in carving a soil profile from its parent material. In some instances chemical reactions cause a change in physical properties, whereas in others, physical changes of the medium either stimulate or retard the chemical processes. This is particularly significant for a distribution of the pedogenic activity throughout the soil body and conspicuous local intensification of certain reactions in particular horizons of the soil profile. For example, an intensification of hydrolysis in some part of the soil body may lead to the formation of more clay in this part than in the others. This addition of clay fundamentally changes the texture, consistence and porosity of the original material. It changes the extent of surface area of the solids, the pattern of the pore space, velocity of movement of the solutions through this part of the soil, and its heat conductivity; it stimulates the development of a new form of structure which is different from that of the original material; it changes its color. Such changes in turn affect the energy and modify the character of the chemical reactions due to which they have been developed.

The pedogenic process operates in a medium characterized by the uneven and continuously changing conditions of temperature and moisture. Diurnal and annual fluctuations of the temperature and humidity of the air do not cease abruptly when the climatic elements emanating from the higher strata of the atmosphere strike the surface of the earth. The climatic waves originated in the atmosphere penetrate the soil for a short distance below its surface. Such a penetration into the soil of the alternating waves of heat and cold as well as of the maximum and minimum moisture is marked by a fast decrease in velocity of transmitting of the heat and moisture from one layer to the other, and by a decrease of the amplitude of waves. This depends upon changes of the medium through which the climatic forces are spreading. From the gaseous medium of the atmosphere

they enter the porous-solid medium of the earth's crust characterized by the different absorbing power and conductivity for both heat and moisture.

The depth of pentration of the climate beyond the surface of the soil is rather small; perhaps, its maximum nowhere exceeds about ten feet. The character of functions of climatic elements beyond the surface of the soil, however, is so different from that above this surface, that the "soil climate" is considered sometimes as something fundamentally different from the "air climate," although such a distinction is, perhaps, not entirely justifiable.

Mechanism of the soil climate can be illustrated by a short discussion of the temperature of the soil body.

Perhaps, the diurnal maximum of temperature on the surface of the soil occurs simultaneously with its maximum in the air above the soil, although in many instances the temperature of the surface soil is considerably higher than that of the air. A few centimeters below the surface the daily maximum will be reached, perhaps an hour later than on the surface. Penetration of the crest of the heat wave (that is, of the daily maximum) for the same distance of a few centimeters below this level will take a much longer time, perhaps three or four hours. At some depths, depending upon the character of the soil and other factors, the daily maximum will be reached when the temperature on the surface will be at the point of diurnal minimum which will send into the soil a wave of relatively low temperature.

Together with a progressively decreasing velocity of penetration of the soil by the alternating relatively warmer and relatively colder waves, the amplitude between the maximum and minimum decreases progressively to a vanishing point also. At some depth from the surface the temperature does not change during the dirunal periods, although it gradually changes from the annual maximum to the annual minimum. The annual waves of heat and chill travel through the soil body slower but penetrate deeper than the diurnal waves. At certain depth the temperature of the soil is not affected by annual changes of the temperature on its surface and remain constant. Perhaps, at this level the climate ceases to affect the earth's crust, and maybe ceases to exist.

The heat is transmitted from a relatively warmer to a relatively colder body. When the surface of the soil is warmer than the interior, the heat wave moves downward. When the surface is colder, it moves upward.

The waves of moisture traverse the soil body in a somewhat similar way although with less regularity. Moreover, the transport of moisture through the soil is affected by the capillary forces, gravity, vaporization, condensation and transpiration by plants.

Consequently the temperature and moisture of the soil, which mutually affect each other, are never uniform throughout the soil's body. These inequalities together with a difference in aeration cause uneven biological and biochemical activity as well as uneven energy of chemical and physical attacks upon the mineral framework of the soil in various sections of the soil, which, in turn, leads to a differentiation of individual genetic soil horizons.

Obviously none of these processes can be fully understood without a knowledge of the thermodynamics and hydrodynamics of the soil, of the chemical and physical composition of the soil body and especially of the behavior of various components in the thermodynamic conditions of the pedogenesis.

Until quite recently the total analyses of the whole soil materials and of some particular mechanical fractions (colloids) separated from such materials formed the backbone of chemical investigations of the soils. These analyses demonstrate a mass effect or a sum total of

chemical changes in different horizons caused by a great many concurrent reactions which take place in the soil, but they fail to demonstrate the individual additives of such a sum total, their nature and their relative value in the summarized effect. The aspect on which these investigations have failed to throw light, however, is of the utmost importance.

The solid phase of the soil is a heterogeneous mixture of many different minerals and every mineral individually is a heterogeneous system of several constituents. A chemical composition of most minerals can not be expressed by stochiometric formulas although each of their constituents is a definite stochiometric compound. Crystallization of minerals from melted magmas or from solutions or meltings, unites these stochiometric compounds into definitely oriented systems (crystals) in certain although not stochiometric proportions. A definite orientation in space of different constituents whether of atoms or of groups of atoms is an essential characteristic of the crystals. The same stochiometric compounds, taken in the same proportions but differently oriented in space in regard to each other, produce the different crystals.

Various minerals behave differently in thermodynamic field of the soil formation in which numerous reactions of decomposition, recrystallization and reorientation of crystals take place. This should demonstrate a complexity of the chemical and physical life of the soil and the inevitability of fatal shortcomings of the summatory analyses to reveal the important details of the mechanics of pedogenesis.

An application of x-ray analyses has opened the door for a new approach to the problem; and in spite of its novelty has already made it clear that soil chemistry will have to lean more and more toward the mineralochemistry in general and the chrystallochemistry in particular. The outstanding problems to be solved by soil chemistry on its new path include not only an investigation of the chemical composition and chemical structure of the minerals which form the solid phase of the soil, but also, and especially, of their behaviors and metamorphism in the thermodynamic environment of the soil formation.

Weathering of the massive rocks and of their fragments, large and microscopically small, is a straight-line geological process. One may trace a gradual transformation of granite into a clay; or of some other rock into a pure quartz sand. The rocks are a source material, the clay and sand, the end product of weathering in the existing conditions. Probably the name, "end product," is not entirely correct. The end product should be a static formation absolutely stable in the given thermodynamic conditions. Such products, even if they actually form, do not accumulate on the surface of the earth; if they would, the earth would be wrapped in an inactive, lifeless mantle. Geological erosion takes care of the removal from the surface of such dying off material as fast as it forms, continuously exposing to weathering fresher material, thus providing a continuous flow of energy and matter into the zone of pedogenesis.

Figuratively speaking, the cyclic pedogenic processes begin where the weathering ends. This does not mean that the beginning of the soil formation ends the weathering. It has already been pointed out that both processes concur in the soil. Weathering continues to attack the mineral framework of a skeleton of the soil within the soil just as actively as outside it, and likely even more actively.

A conspicuous feature of the strictly pedogenic processes is the participating of the living substance in them. In fact the sphere of soil formation can be determined as a part of the crust of weathering invaded by living organisms. The relationship between the soil and living nature is so close that without much ex-

aggeration it can be said that the soil is a storeroom, a nursery, a bridal hall and a cemetery of the entire organic world.

A general trend of the biolgical activity and the biological pressure determine the character of the soil more effectively than any other factor and probably even more than all the other factors together. Organisms involve into the pedogenic cycles tremendous amounts of radiant energy and the new elements such as carbon and nitrogen. Moreover, if the weathering of a mineral framework of the soil does not keep pace with the energy and requirements of the life, living substance itself stimulates the weathering and attacks the minerals with powerful enzymes.

An introduction of life immensely increases the complexity of a pedogenic process. It adds an immense variety of organisms to the multitude of minerals. The living substance, or a sum total of living organisms covers the surface of the earth by an almost continuous film. This substance represents a peculiar geochemical formation. Probably it is a crown of weathering, its final and the most elaborate product. The outstanding features of this formation are its dissemination into innumerable individual organisms each of them enjoying a relative independence from the others; its continuous and rather fast renovation, and an exceedingly high dynamism. The distribution of living substance throughout the land surface, its congestion in some particular region and a relative scantiness in the others, is regulated by the natural environment. The amount of life at any particular place is in equilibrium with its environment which determines certain limits for the expansion of life. Within these limits the life, so to say, saturates the surface of the earth. Such a saturation point is a point of equilibrium. At any particular and stable environment, the amount of life is relatively constant and represents a grade of the biological pressure adjusted to this environment.

Biological pressure, whether expressed in tons of living substance per unit area or in quanta of its energy, is one of the most powerful factors of pedogenesis. The field of pedogenic activity is swarming with micro- and macrobiological population, is thoroughly penetrated by the roots, blanketed with organic residues and enriched by the products of decomposition of these residues. These react with the products of decomposition of minerals. Various exothermic and endothermic reactions are taking place, and it is this ceaseless activity, this continuous flow of energy and matter, which makes the soil a dynamic system.

A laboratory investigation of soil chemistry and physics is made in samples of soil material. The soil material, however, is not a dynamic soil. The samples of soil material do not represent the soil any better than a piece of wood represents a living tree. Therefore soil physicist and soil chemist know that sooner or later they will have to take their precious instruments and reagents to the field and there check their diagnoses on a living body of soil. They know that what they are studying now in laboratories is only a preliminary exploration of the fundamental laws which control the function of soil formation in nature.

Naturally most of the investigations in the field of soil physics and chemistry are concerned with some particular aspects of the problem. Many of them are not as yet properly coordinated with each other due to the vastness and relative novelty of the field. Much work still remains to be done before the fundamental problem of soil dynamics can be attacked. This problem is concerned with the soil-forming cycles of energy accompanying the cycles of matter and with giving to the process an exact mathematical expression.

THE PHYSICIST AND EVOLVING CIVILIZATION

By Dr. LEWI TONKS

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NOT so many years ago the run-of-the-mill citizen thought of a chemist as the man in the drug store who made up the doctor's prescription, and he thought of an engineer as one who had charge of the machinery of a steamship or who chauffeured a locomotive. The chemist, because of his well-defined field of operations, and some excellent publicity, has come to be recognized for what he is, a manipulator of atoms and groups of atoms who investigates how and under what circumstances they join with each other or part from each other to form new substances with new properties. The engineer, also, even more than the chemist, is now recognized in his role, for he is the industrial interpreter of scientific progress.

But I am afraid that even to-day the science of physics remains a somewhat nebulous concept to the man in the street. There is a persisting spontaneous association—which is vaguely known to be wrong—of physicists with castor oil. One reason for this is that the purveyors of physics for consumption always appear incognito as doctors, astronomers, marine engineers, aeronautical and communication engineers, and many others. There is no such thing as a physical engineer. The field of physics is broad, and each of its manifold subdivisions has its own name which, with few exceptions, contains no "physics."

Physics is broad because it has to do with the properties of matter in general, in those changes and relations which do not involve chemical change. It is true that the simpler manifestations of physics seem far less mysterious than those of chemistry. The floating of a stick on water does not have the mystifying quality of its consumption by fire. Nevertheless, the nature of atoms, what they are composed of, their relation to electricity, their disruption and reformation, their interaction with light, the nature of collisions between them, are all physical questions. We must add to this list the laws of atomic dynamics which bridge the gap between physical and chemical properties. It thus appears that a synthesis of the physics of the atom must lead to its chemistry so that physics is the fundamental science. Its effect on mathematics will appear shortly. Through chemistry, but also through the tools for which it is responsible, physics also underlies biology, medicine and even psychology.

No one phase of human activity can be separated from the social organization as a whole. This is true of science. Down the course of history the cross-links have been manifold between science and other human activities, the production processes, trade and communication, warfare and the arts. The needs of an era have given direction to the scientific activities and scientific discovery has reacted on society. The slogan of science for science's sake is as false historically as it would be sterile socially.

The Egyptians were faced by the problem of surveying the landholdings which the Nile inundated. The river often changed its bed and it was necessary to re-establish boundaries and areas for taxation purposes. As a result they laid the foundations of geometry. It was healthy because it was empirical. It was amazingly exact. Later the Greeks were to systematize it with good

results, but were also to distill it from its earth-born origin into the realm of pure thought, with unfortunate results.

In the same era there was sufficient optical knowledge for the design of simple optical instruments. The Alexandrians knew the fundamental law of magnification, and Euclid treated the geometrical principles of reflection. Ptolemy had investigated the law of refraction and Archimedes is supposed to have constructed concave mirrors to use as burning glasses. Yet the social needs which were to stimulate the exploitation of this knowledge did not arise until the Dark Ages had passed. Then the advent of printed books created the need for an aid to vision and spectacles were invented. Two spectacle lenses made a telescope, which, turned to the heavens, helped solve the important problem of determining longitude on the long western voyages of that age. Newton's interest in the refraction of light is traceable to the colored fringes which invariably surrounded the images in the early optical instruments.

This gets us somewhat ahead of our story. Archimedes was also interested in levers and was prepared to move the world, if only some one would furnish a fulcrum. Nothing much seems to have come of this, although here was a possible foundation for a development of machines. On the other hand, music, athletics, architecture, sculpture, the drama and philosophy flourished. These fields were the natural outlets for the social energy of citizens whose material needs were taken care of by slaves. A slave economy is not conducive to scientific advance, for those who engage in the productive processes have no incentive, and contact with crude matter is beneath the social status of the citizen.

The sun and the stars in their courses furnished mankind with his only clock and calendar at the earliest stages of civilization. The positions of the stars at sunrise or sunset determined the sowing of crops or the preparation for the rainy season. The study of the heavenly motions naturally followed. The geocentric view could suffice until the determination of longitude at sea made a simpler scheme for predicting the positions of the planets desirable. The Copernican theory met this practical necessity and came into general use in navigation long before there was adequate evidence for its adoption.

Even that pseudo-science, alchemy, was a response to a pressing social need. The ruling classes of the dark ages had need of greater income for their wars and their living than the serfs with their slow rate of wealth production could supply. Gold was the desideratum, and alchemy proposed to supply it. May I point out that to-day we can produce wealth faster than we are prepared, socially, to use it. Power lies in other things than gold. That we go on mining it makes us appear even more foolish than the alchemists.

We know from his writings that Newton was interested in the problems of industry and commerce. Artillery was a new weapon in his time, but the laws of ballistics had not been discovered. Newton laid the foundations of this branch of science when he formulated his three laws of motion.

It is worth noting that the group whose meetings marked the beginning of the Royal Society of England, for years the leading scientific society of the world, drew up an outline of their prospective endeavors. To quote a chronicler who recorded their purposes:

> They design the multiplying and beautifying of the mechanick arts. . . . They intend the perfection of graving, statuary, limning, coining and all the works of smiths in iron or steel or silver. . . . They purpose the trial of all manner of operations by Fire. . . . They resolve to restore, to enlarge, to examine Physick. . . . They have bestowed much consideration on the propagation of Fruits and trees. . . . They have principally consulted the Advancement of Navigation. . . . They have employed much Time in

examining the Fabrick of Ships, the forms of their sails, the shapes of their keels, the sorts of Timber, the planting of Fir, the bettering of pitch and Tar and Tackling.

We have come far since those days. The theory of relativity has stripped the cloak of mysticism from space and time, laying bare their intimate relation to—yes, their interdependence with matter and energy. Quantum theory rubs noses with practicality in the electric eye, x-rays, mercury arc rectifiers, sodium lamps, fluorescent lighting. Wave mechanics links the strength of materials to the conduction of electricity in metals, and to the non-conduction of insulators.

In any discussion of the relation of science to human advancement it is necessary to recognize the difference between the scientific approach, which is rooted in actual facts and relationships, and counterfeit science, which reaches conclusions by arguing from intellectually acceptable premises. What makes it counterfeit is that the premises, while possibly related to facts, exist on a supposedly higher plane of reality which puts them beyond empirical test. Yet the conclusions from these premises are supposed to have validity in the world of reality.

The physical sciences have largely rid themselves of this incubus, but because the social sciences have not it is worth while to look back at a famous example. It is Euclidean geometry.

The supposedly self-evident postulates of that system were no more than a summary of then existing geometrical experience with physical objects. But the philosopher requires something beyond empiricism. Accordingly, this limited realm of human experience must needs be endowed with a super reality so that universally valid conclusions can be reached. The progress of science was, however, to deflate such intellectual arrogance by showing that only within distances ranging between several atomic diameters and several times the earth-moon distance was Euclidean geometry valid, and only as far as we could tell in view of our inaccuracy of measurement. Mathematicians, themselves, were to show that Euclidean plane geometry was only a special case of the two-dimensional geometry of surfaces in general.

This should not be construed as an indictment of pure mathematics. Since the Grecian era the mathematician has become more sophisticated. He knows now that he is interested in exploring as far as he can the relations of a set of concepts which may or may not bear any resemblance to parts of the physical world. Unhampered by questions of physical reality, he has investigated many possible types of relationship and deduced the consequences thereof. The scientific value of these self-consistent flights of pure fancy lies in the circumstance that time and again a certain portion of the physical world has been discovered to be linked together more or less exactly in accordance with one of these sets of mathematical assumptions. And then the theory can be applied as a whole.

Imaginary numbers are a case in point. The square root of minus one, $\sqrt{-1}$, was invented by the mathematician to fill a gap in the real number system, for in that system the square roots of negative numbers do not exist. The mathematician had the satisfaction of finding that the newcomer helped to explain the behavior of real numbers, but otherwise it was purely ornamental.

Meanwhile the electrical art was developing. Certain advantages were appearing in the use of alternating rather than direct current. It became necessary to find a mathematical technique appropriate to the new physical relationships. The mathematician had it ready to hand in his explorations with $\sqrt{-1}$. And so they were married, $\sqrt{-1}$ to 60 cycles, and they have lived together happily and usefully ever since.

It would be wrong if I left you with

the impression that scientists have not been guilty of the sins of pure reason in their own field. Time and again scientists have been baffled by seeming contradictions, which were only contradictions in terms of a description carried over into a newer region of nature from a well-explored region. We have had to learn, for instance, that the laws of the world of baseballs and balloons are the syntheses of those that describe the world of nuclei, atoms and light quanta, and that for astronomical distances, times, temperatures and pressures still another description is required.

Having already discussed the general historical relation of science to society, I want now to examine a few of its more fundamental contemporary social consequences. What the more recent specific contributions of physics to our mode of life have been can well be left to such an excellent book as Professor Harrison's "Atoms in Action."

It is instructive to spend a few minutes in examining a single scientific development. It would be hopeless to try to reproduce all the groping, searching, thinking, guessing, trying, testing and repeating of tests that are an essential part of the scientific method in action. What I hope you will grasp is some of this, and also some idea of the diversity of specialized knowledge and skills which must be tapped and the material resources which have to be available. What is chosen for examination is of little moment. A brief chapter from the history of the incandescent electric light will do as well as anything.

The new incandescent lamp of 1911 had a filament of drawn tungsten wire in an evacuated glass envelope. The isolation of tungsten had been a chemical contribution, its drawing into fine wire a triumph of metallurgy. The outstanding suitability of tungsten as the filamentary material was recognized as a consequence of its high melting point, for the study of heat had revealed that the higher the temperature of a body, the greater the fraction of the energy from it which appears as visible light.

The creation of a sufficiently good vacuum was the culmination of a development which von Guericke had started with the invention of the first air pump and which was to reach its final stage, as of to-day, in the non-mechanical condensation pump in which a condensible gas of heavy molecules like mercury vapor is used to blow the lighter molecules of air and water vapor out of the vessel to be exhausted. The mercury vapor is not actually blown through the lamp, but the same effect is obtained by connecting the lamp to the pump in which a blast of the vapor entrains the air molecules. A cold zone in the connection to the pump, kept cold with liquid air, prevents mercury from getting into the lamp, and the mercury in the exhausted gas is condensed out by cooling with water.

The art of glass making and blowing was necessary to the bulb. To carry the current from outside to inside a metal whose expansion with temperature matched that of the glass had to be used. If this metal shrank too rapidly on cooling it would pull away from the glass as the seal cooled, and if it shrank too slowly the stress created on cooling would crack the glass.

One undesirable feature of the lamp was its blackening with use. This was thought to be due to chemical attack on the filament by gases which developed inside the bulb. But practically nothing was known about chemical reactions in the range between 2,000 and 3,000° C.

Research was undertaken primarily to gain an understanding of phenomena which occur at low gas pressures and high temperatures. It developed the following facts which are a few among many others of great importance. Glass contains large quantities of water which is given up to a vacuum when the glass is heated. This evolution of water vapor

continues for many hours at any temperature, but by heating the glass above the temperature at which it will be finally used, it can be reduced to a negligible amount. A minute quantity of water vapor induces a progressive blackening of the glass, as does hydrogen, which strangely enough does not react with tungsten. On the other hand, oxygen, which does react with tungsten, has no such effect.

These were valuable facts, but of equal significance was the discovery that even when all trace of deleterious gas was permanently absent, blackening still occurred. This was discovered to be the result of the natural thermal evaporation of the tungsten. At the time it appeared to offer an insuperable barrier to a further increase in lamp efficiency.

The all-important reason for using vacuum was that this eliminated heat loss by circulation of the gas within the bulb and thereby increased the efficiency. On the other hand, further investigation of the effects of gases on tungsten showed that the presence of an inert gas cut down the blackening of the bulb. Was it possible that gas would permit a sufficient rise in filament temperature so that the relative increase in light emission would more than compensate for the new convection heat loss. The laws of heat flow in gases, which had been worked out in the course of the same research, were applied, and the answer was yes, but only for filaments of an impossibly large diameter so far as common use was concerned. The difficulty could be solved by coiling the filament, for then its electrical characteristics would be those of the fine wire while its heat losses would be those of a heavy one. An ingenious solution, which, however, required a so-called nonsag filament, one which would retain its coiled shape throughout its life. Here was a metallurgical problem again. Its solution involved another about-face in the constitution of the filament. Originally of tungsten, it had been found necessary to introduce thoria if the filament was not to disintegrate on alternating current. Now the purity of the wire had to be reestablished, but a revised heat and mechanical treatment was found which developed long interlocking crystals in the wire.

This account shows you a small section of science at work, exhibiting its approach, its needs, its ramifications, its power and its consequences. The approach is that of full knowledge of what has been discovered before, and acknowledged ignorance of the new things which must be found out.

Its needs of specialized knowledge in research and development can only be filled by having a staff of specialists available for work and consultation. And each scientific and engineering advance creates its own experts in its wake.

Each contributing specialized field brings its own materials and equipment to the new task. Machine tools, microscopes, meters, thermocouples, gauges, power supplies and so on are among them.

Its consequences are the creation of new satisfactions for human needs and desires with an expenditure of less effort per unit produced.

Its ramifications arise from the unsuspected relations and undreamed-of effects that are discovered. It is these which will be most fruitful in the future. One such effect has already been mentioned, that of a gas cutting down the rate of evaporation of the filament. The incandescent lamp research also elucidated another effect whose importance was destined to equal that of the light.

Edison had found in his lamps that an electric current would flow in the vacuum between the hot filament and another electrode. Langmuir proved that a similar current flow in tungsten filament lamps was due to electrons

evaporated continually out of the hot tungsten. There was, seemingly, an opportunity for considerable electric current, carried by the electrons, to flow between the ends of the filament where the voltage difference was greatest. This phenomenon was the doorway to radio. The key to the door was the answer to the question: What limits the electron flow from a hot filament and keeps it very small even though the temperature is raised? The answer is: The mutual repulsion of the electrons whereby those which are traversing the vacuum retard the escape of their successors from the hot metal. Not only radio, but the modern telephone system, and most of our methods of automatic control and recording are corollaries of the answer to that question.

What we have seen in our small sample of scientific endeavor is typical. It shows us that large social and economic resources must be available to create, gather together and hold the technical personnel and the physical plant. These resources are necessary at each level of progress, namely in fundamental research, in the development of a product, in its production and in the further exploitation of the experience gained.

The result is that science itself is a potent factor in the development of big business. There are other factors, to be sure, chief among which I should put the advantage of monopoly in a capitalist system. But the logic of scientific progress points to large highly integrated units of development and production quite apart from the economic organization of society. The day of the individual researcher is past. The pattern now is one of cooperative interlocking effort. This is as true in medicine as in television. If you want insulin and sulfanilimide you will have to accept big industry, too.

I have been at some pains to contrast the Aristotelian approach as exemplified by Euclid with the scientific method as illustrated in the electric light. I have tried to bring out that the self-evident nature of postulates is no guarantee either of their validity or the range within which they are valid, but that the ultimate arbiter is nature herself. Time and again nature has brought us up short with the proof that she is infinitely more versatile and ingenious than even the mind of a genius. I think we have learned this lesson with regard to the physical world. Galileo, Copernicus, Einstein and Planck are all names associated with revolutions in scientific thought. The associated advances only had to be revolutions because this lesson had not been learned.

This lesson is still unlearned, however, with regard to the world of human affairs. In economics, we have, I think, discarded the Economic Man, and we do not hear so much about the Law of Diminishing Returns. But the authorities still appeal to the Law of Supply and Demand. Demand, how expressed? By cash bid, by promise to pay, by petition or by elemental human needs? Demand for what? Opium, gin, a decent standard of income, food, coming-out parties or jobs? Supply—how adequate in volume and quality, delivered where and how long hence? "No," our Aristotelian economist may say, "the law is more general than you would imply. Demand means *effective* demand, and certainly there are limitations on supply set by the economic and social circumstances of the time and locality." Perhaps this is a poor defense, but in my brief excursion into economic theory I found no other. Let us incorporate the explanation into the statement of the law. Here is what we have: If a demand is effective in augmenting the supply, then the supply will increase, but some demands can not effect an increase because of circumstances. Does this say anything at all, let alone express a funda-

mental economic relation? Hadn't we better forget it and start fresh with a detailed analysis of all the controlling factors?

We are hearing much about the stimulation of private enterprise. How "private" are enterprises whose owners number from the thousands into the millions? I hardly believe that the users of the term refer to the comparatively small number who own the bulk of the stock or to the increasing control by the managing personnel. How "private" is a corporation which controls a substantial portion of the transportation facilities, which have become a necessary part of our life, whether rail, air, water or automotive? How "private" is a corporation which either openly or secretly or in both ways uses its concentrated resources to influence legislation? And the word "stimulate" could bear a little historical and factual examination.

Examples could be multiplied. I cite one more. It is common practice to begin a socio-economic discussion with the premise: All of us are divided into three parts, capital, labor and the public. Apparently the white-collar middle class must be the public because we are classed neither with capital nor labor though we do earn our living. And aren't the capitalist and the worker part of the public? If wages are increased too much (what is "too much" relative to actual union demands?) then the public, we are told, won't be able to buy the product. Are these analysts really afraid that the increase in wages will be banked, as is happening to so much income at the present time? No valid conclusions can flow from this stereotyped erroneous subdivision of the population which is incomplete in its enumeration and overlooks essential interrelations.

I believe that we are making some progress in the direction of science in human relations. More and more factual studies from which limited conclusions can be drawn are being made. But we are advancing far too slowly. The advance is slow because we are half blind to the possibility of applying science and also because of active opposition. It is too slow because in recent years our social maladjustments have been accumulating more rapidly than our power to deal with them.

An outstanding characteristic of the world that science has created is that the individual no longer controls the elemental production processes. The processes have themselves become too intricate and subdivided. The truck gardener probably comes closest to control, but he is absolutely dependent on gasoline, electricity, automobiles and the textile industry. At a more primitive stage each of us had a less perfect but a direct control over our sources of supply and means of fabrication. In perfecting our control of nature, however, to increase her bounty and mitigate her severity we have developed a new system of human relations whose essential functioning is as unknown to us now as were the relations between the earth, sun, moon, planets and stars before Copernicus and Kepler.

In both cases the existing knowledge had been sufficient for many purposes; in both cases powerful forces were arrayed against the logic of the facts which were accumulating. The essential difference in the two situations is this: The astronomical makeshifts could have been elaborated indefinitely. There was no critical urgency in the need for the simpler navigation methods which the Copernican view made possible. On the other hand, the maladjustments in our social arrangements have already resulted in positive retrogression in large sections of modern civilization. In our own country the expedients to which we have been temporarily forced appear to be increasingly necessary and at the same time increasingly impossible to maintain.

Is there any consensus of opinion that the gathering and correlation of social and economic facts should be vastly expanded? Are scientists more inclined than others to ask for this extension of a fruitful technique? In England some of them have developed a social awareness that has not been exhibited in this country. Here the scientist reserves his independence of thought and the inquiring attitude for his special field. As a scientist he is right-handed and as a citizen he is left-handed, and he lets not his right hand know what his left hand doeth.

One excuse that lacks either candor or intelligence is that experimentation is an essential part of the scientific method, and you can not experiment with human beings on a social scale.

The answer to this is twofold. We do experiment. Russia is one example, the settlement of Alaska another. Free public education, every educational innovation and every change in a social institution from the Montessori method to the TVA and socialized medicine is an experiment.

Second, many sciences do not find it possible to experiment. Astronomers, for instance. The one astronomical experiment I know of was that of Joshua, who made the sun stand still, and, scientifically speaking, it was a failure because no one has been able to repeat it. Geology is a science, but what geologist has ever made a fossil in the laboratory?

In somewhat similar vein is the belief that there is an essential difference between the relations of individualistic, thinking, emotional and willful human beings and those subsisting in the lower orders of life, and that this difference transcends the application of the scientific method. This is reminiscent of a conviction that has been widely held that the chemistry of life-processes was essentially different from the chemistry of the test-tube. The laboratory synthesis of urea in 1828 effectively disposed of that view. But let us discuss the newer version.

The present threat to our culture does not arise from factors which are unique from person to person. It arises from more or less universal characteristics in the interrelations between man and his social institutions. There are certainly variations from the norm which differ in magnitude; and some of these variations may themselves be large enough and common enough to be of significance. But scientific method is prepared for this contingency just as mathematics was ready with the $\sqrt{-1}$. In the study of gases physics has synthesized the individualistic behavior of atoms to derive the gas laws. A whole branch of the science is devoted to problems akin to this. It is called statistical mechanics.

As a matter of fact there is an existing social institution which within the limitations of its function applies statistics to a highly variable contingency of human life—namely, death. It is worth noting that the chief threat to life insurance in the last thirty years has come not from the additional mortality of the First World War but from the developing economic instability of our society itself. The variations from the average are also recognized in this institution, because, among others, those afflicted with syphilis, tuberculosis or diabetes can not avail themselves of it.

But more cogent than these arguments is the fact that social studies have been made and have established important relations within our culture which could only be speculated about before.

I do not assert the imperative necessity for our culture to extend its use of science without realizing that the opposition to this step is tremendous. On the whole it is probable that science on its traditional ground has had an easier time of it, even though it has, on occa-

sion, trod on tender but powerful ecclesiastical toes. In its application to social problems, however, it finds two enemies, those who fear that their moral preconceptions may not square with the implications of the facts and those whose economic interests and social prestige are threatened. The latter can command powerful weapons, which have been created by science itself, to combat its extension and nullify its power. This is a contingency which lies outside the power of science to deal with. Stars, triangles, atoms and fruit-flies do not talk back, but those whose social functions are obsolete do this, and more. The situation calls for a greater awareness of the threat to our culture and the will to get the facts without which a solution is impossible.

THE GROWTH OF AN IDEA

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THE "idea" in this case is the conviction that *musical talent is subject to scientific analysis and can be measured.* Some forty odd years ago a colleague in the university faculty who was a very fine violinist kept boasting what a fine musical ear he had. One day I rose to the occasion and said, "Van, I'll find out how good your ear is by measuring it." The challenge was accepted, I devised the apparatus, made the measurement and found that he could hear a difference of about one seventieth of a tone. This was an objective fact, specific and verifiable.

At that time it was a new idea that one could measure specific personal traits quantitatively. Terms like differential psychology, individual differences, talent chart, I.Q., vocational guidance, educational measurements, statistical methods, applied psychology, the psychology of music and many other facts about the recognition of the individual and his personal equation which now loom up so large were at that time practically unknown.

It is my purpose here to illustrate in a somewhat intimate and personal way the normal growth of laboratory research from a germinating idea as it can be traced in the Iowa laboratory. My treatment must, of necessity, take the form of evaluation and bold touches in highlights rather than the amassing of descriptive facts and details.

Van's sense of pitch had been measured, but what did it mean? To answer that question in part, I measured myself, and, to the surprise of both of us, I found that my ear was as sensitive as his. But this did not leave us much wiser, although on more nearly equal terms. So I measured the sense of pitch in a class of thirty students and found that they varied from the ability to hear approximately one hundredth of a tone to the inability to hear a difference of one-half tone. This then was the beginning of a new scale of interpretation. Van and I could compare ourselves with others. This measurement was repeated upon hundreds of adults, and reliable norms of distribution of capacity were established.

The question then arose: What is the cause of these very large differences? When we found that of two normal persons, one may be more than one hundred times as keen as the other in pitch discrimination and that this is relatively fixed, our first resort was to refer it to differences of intelligence or powers of observation; but, to our astonishment,

we found that there was no significant correlation between the sense of pitch and intelligence. Indeed, the student who made the poorest record in the sense of pitch in my original series was one of the brightest of the class and is now a member of the faculty of the University of Iowa.

The next hypothesis was that it might be due to training. To verify this, we first correlated the records on the sense of pitch with the records on the amount of training in music that each student had had and found that there was no significant relationship. That is, a keen sense of pitch is not due to training. To verify this startling find we took all the children in an eighth-grade room and gave them the most intensive training possible in this specific act daily for a month, and we found that the distribution and degree of ability in this task remained practically the same at the end of the training as it had been before training.

At that time it was believed, on the basis of certain experimental evidence, that pitch develops with the age of the child, but our eighth-grade children had done as well as the university students. This was contrary to musical and educational theory at that time. We therefore established age norms from ten years old and up and found that aside from development in the capacity to apply themselves to a task of this kind, there was no evidence of improvement in the sense of pitch with age. In spite of the fact that normal persons show astonishingly large individual differences in capacity for pitch discrimination, it is found that this capacity does not vary consistently with age, intelligence or training.

Applying this to the evaluation of our first measurement upon Van and myself, we may say that our sense of pitch falls within the highest two per cent. in a normal community; that it is probably a fixed, inborn talent which is relatively independent of general intelligence and age; and that it improves with musical training only in the same sense that the acuity of vision improves with training in art production or appreciation. It must be clear to any one that all these psychological facts are of extraordinary educational, social, musical and economic significance.

These first and radical findings launched us upon a program for an intensive study of the sense of pitch which is still in progress and has borne most gratifying fruit in our knowledge about this type of individual differences as involving principles of pure psychology, and applications of this knowledge in anthropology, genetic psychology, heredity, music and education. Through this, our concept of a musical talent has been enriched and vitalized and we have discovered its basic role in countless situations in daily life, art and industry, where its presence had not been recognized before.

It was natural, then, that we should ask: What other talents may be analogous to this? This led us into an investigation of a number of recognizable units in the complex forms of pitch hearing, as in the hearing of consonance, harmony, melody and various types of modulations of pitch; and this led to the beginning of what we may call "the psychology of pitch."

We then made an objective analysis of tone to determine the characteristics of the sound wave and found that there are four and only four; namely, frequency, amplitude, duration and wave form. For the hearing of each of these characteristics of tone we recognized the necessity of a specific capacity; namely, the sense of pitch, the sense of loudness, the sense of time and the sense of timbre. These cover the tonal, the dynamic, the temporal and the qualitative attributes of sound.

We then entered upon a program of

measurement and analysis of each of these on the pattern of the studies on pitch and followed these four basic factors into their variants, combinations and interrelations in the actual musical situation. This gave us a sound basis for the analysis of musical hearing.

For each capacity for musical hearing, both simple and complex forms, we must look for a corresponding capacity for performance or tone production. This gave us a classification of the motor capacities necessary for the control of sound in a musical performance.

This parallel classification of sensory and motor processes based upon the four characteristics of the sound wave was found to carry through the higher mental processes of memory and imagination, the higher cognitive processes of conception, judgment and reasoning, and the various aspects of feeling and emotion and all types of musical action. That is, when we remember a musical selection, imagine it, think and reason about it, and analyze our musical feelings and all types of musical action, it is always in terms of one or more of these four factors or their derivatives. They constitute the content to which the music gives form. All musical creation, as in composition, is but the artistic arrangement of these four elements in musical content. All appreciation of music is in these terms. All mastery of musical performance may be expressed in these terms.

Recognition of this type of classification constituted a preliminary survey of our field for investigation and made elements of musical experience and behavior tangible for measurement and analysis in the laboratory. Thus we found ourselves in a most fascinating new field with opportunities for blazing trails in hundreds of directions theretofore unexplored. This new field we now call "psychology of music." As the field broadened, we found ourselves constantly drawing upon and contributing to general principles of psychology and were thrown into cooperation with allied and underlying sciences on a large scale.

It was gratifying to find that this subject could be treated either as pure or applied psychology, that the applied aspects might be treated experimentally in the same manner as problems of pure psychology and that the interests of pure psychology could be served in as clear and unhampered manner when a practical application was in mind as when it was not. We found ourselves constantly drawing upon and contributing to general principles of psychology and had to branch out in cooperation with allied and underlying sciences. Fascinated by the magnitude and the immediate yield in this field of the science of sound, the staff and equipment of the laboratory was for many years concentrated upon this objective at a sacrifice of many other possible laboratory interests.

At that time there were no other laboratories equipped for this operation; at every turn we were blazing new trails. The matter of equipment was and is yet a constant problem calling for ingenuity, invention and facilities for the building of instruments. The opening up of a new field of investigation calls for new types of equipment, means of measuring every aspect of sound, means for producing all musically significant types of sound, means for the analysis of each and every feature of the sound and means for the complete phonophotographic record of any musical performance. This represents a bewildering nest of complicated instruments. Fortunately, the psychology of music was really made possible by the extraordinary progress of invention and provision of instruments which came in through the commercially profitable and scientifically intriguing developments in radio engineering. Without these, the

best contributions of any university laboratory would have been insignificant.

But instruments are mere tools. They must be designed for specific problems. We could not shoot at the blue sky of all the psychology of music, and therefore we had to pick specific aspects which from time to time became tangible and significant. Of these, there was an abundance, all bearing directly or indirectly on the problem of laying scientific foundations for some phase of the art of music. One of the constant problems is the experimental definition of terms. Timbre, for example, was but little more than a French name. A permanent and verifiable definition had to be determined by experiment, and the loose musical jargon hovering around that concept had to be scrapped in favor of the experimentally determined definition of the word. This was the first step in the assignment of an understandable and vital function to timbre in music. Prevailing theories had to be submitted to verification, as in the case of the laws of harmony, action of the vocal cords, musical phrasing and scales. Our extensive publications of researches on such specific issues of musical experience and behavior tell an interesting story.

But the effort to deal with any single problem of musical sounds at once took us into allied fields, such as the perennial problems of heredity and environment and the science of genetics, the physics of sound, the physiology of hearing, the endocrine basis for emotion and electrophysiology of nervous control. Since the object of the investigation was music, there had to be constant rapport with current leaders in musical theory, education and criticism. The barriers among such fields have broken down, and in the last fifty years progress has been made by leaps and bounds. As a result of the recent development in acoustics in the interests of radio and all other forms of sound engineering, we had in most cases only to share and help to harvest the common findings.

Out of the science built from all these sources, new applied sciences have gradually emerged. Mastery of the measurement of musical talents took us into the midst of a practical field of musical education. As the measurement of musical talents became recognized as a scientific approach to the problem of individual differences, differential psychology took many new turns. Refinement of mental measurement in hearing led to special fields of mental testing. When we went into the World War, we had to answer the question: What can psychology contribute? and some notable contributions came from the psychology of music in the location of U-boats and the selection of personnel. Musical anthropology took a new scientific turn. All we had learned in the study of musical sounds had its parallel and counterpart in speech, and hence arose the psychology of speech. While each of the arts has its medium, they all have certain principles, talents and goals in common. In recognition of this, there grew up in the laboratory a separate division of the psychology of graphic and plastic arts. Musical anthropology which had previously been loose observation turned experimental. As we learned to record and interpret musical performance, problems arose in regard to what is possible and what is good in musical performance. And through the years of accumulation of musical terminology, classification and experimental theory, we found ourselves laying foundations for a scientific musical esthetics. None of these problems has been solved, but the mere naming gives us some conception of the richness of possibilities of a new field, such as that of the psychology of music.

While much of the overhead work in the Iowa laboratory has been my happy

lot, the accomplishments in the whole program must be accredited to the large body of students and colleagues in the department who have shared in the building up of the laboratory. It must be clearly understood that the progress in large as we now see it is not the work of a single laboratory or the fruitage of a single idea but rather the integrated findings of many interlocking sciences, of many laboratories in each science and often of many individuals in the laboratory. May I add also that the type of specialization here involved has furnished the workers in the field an excellent opportunity for broadening the scientific horizon and extending the vision into approaches to the science of the art of music.

Such is a sort of privileged retrospect under the license for reminiscence extended to an old man who has lived through much of it. Perhaps the picture is overdrawn. However, every statement is subject to verification. I have tried to see the development in relief, especially as it germinated and rose into the structure of a scientific family tree in rich branching with foliage and fruiting. The germinating idea was that "it can be done"; musical talents can be measured. There was no sudden leap from the sprouting of this idea up to the present level of achievements; but progress was made by continuous logical and tireless work going by natural steps from one stage to another. The germinating idea was not exactly new; it was simply vitalized and thrown into line with parallel developments. Perhaps the most all-impressive contribution that has come out of this entire development is the revelation of how little we know of such a "knowable" subject.

CAN THE UNITED STATES HAVE BUTTER AND GUNS?

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The slogan, "Guns for Butter," which epitomized the German campaign to re-arm, also powerfully expresses the place of vegetable and animal fats and oils in the modern industrial economy, and more especially, in the economies of warring nations. Numerous tales and incidents reported in our daily papers are constantly emphasizing and re-emphasizing the strategic importance of fats and oils. Most of us have read stories about the Germans limiting the number of baths so that soap may be saved. We are all aware that Germany is raiding Denmark for its butter, and that margarine is being strictly rationed in Britain. Occasionally we hear of such desperate measures as that taken by France in sending a portion of its fleet to Dakar to escort back freighters loaded with vegetable oils. Yet few people realize that our own country would also be faced by an acute problem if our imports of vegetable oils and fats were cut off.

The annual consumption of animal and vegetable oils and fats in the United States is over 71 pounds per capita, a figure which far outstrips that of any other large nation. Certainly, in view of this, animal and vegetable oils and fats must be considered as we plan for national defense or for any economic, political or military emer-

gency which might arise. Since the supply of animal fats and oils produced in the United States is normally adequate, the problems associated with vegetable oils and fats will be stressed in this discussion.

Perhaps the importance of vegetable oils and fats in our everyday life, in our industrial life and in our projected preparedness program may best be emphasized by listing some of the products which, in whole or in part, are obtained from them. These run the gamut from the oil in which our sardines are packed to the high-grade lubricating grease used in airplanes, from the paint on our cars to the candle burning in a backwoods home, and from the linoleum on our kitchen floors to the shampoo we use on our hair. In listing these products in the order of their quantitative importance, first place is occupied by shortening, vegetable fats having taken over that function from lard (Fig. 1). In second place is soap, about one half of which is made from vegetable oils and fats. Nearly all the best quality soaps used for personal purposes are manufactured from vegetable oils and fats. Next in order is oleomargarine, followed by other edible oils (salad oils, etc.), and paints and varnishes. Less important from the standpoint of amount consumed, but of great importance because of their strategic values, are such products as linoleum, oil cloth, printing inks, high-grade lubricants, and especially glycerine and nitroglycerine, from which explosives are manufactured. Vegetable oil is also utilized for quenching steel, as a flux in the tinplating process, and as a base for dyes.

Vegetable oils and fats are obtained from a great variety of plants belonging to a number of plant orders. Usually the seed is the source of the oil, although in some cases the oil is obtained from the fleshy pulp of the fruit. In the case of the oil palm the oil is obtained from both the pulp and the kernel. Plant oils or fats are classified mainly according to their drying or edible qualities or according to their consistency. Drying oils are those which, upon exposure to the air, have their exposed surfaces oxidized into a leathery skin, and are thus invaluable for the production of paints and varnishes. Some oils are considered semi-drying, that is, with but little processing can be made into drying oils. Soybean oil may be cited as an example of a semi-drying oil. Edible oils are those which are most palatable, which have high food value and which usually are non-drying. A wide variation in classification is possible since certain oils change from the edible to the non-edible class, or from the drying to the non-drying class, as prices fluctuate or as new processes for treating them are developed.

The basic difference between an oil and a fat lies in their consistency at normal temperatures. Usually the original plant product is an oil, but by the process of hydrogenation this oil can be changed into a fat. It was the perfecting of this process of hydrogenation about forty years ago that led to the introduction of oleomargarine as a butter substitute. Since then vegetable oils have been more than co-equal to animal oils in world consumption and trade. Even in the United States, where animal oils and fats are still significant, the average consumption, exclusive of butter, is only 23 pounds per person as compared to a vegetable oils and fats consumption of over 30 pounds per person.

Almost three and one half billion pounds of vegetable oils and fats were consumed in the factories of the United States in 1938. Just how the present rearmament program will affect us is problematical, but no doubt an increase in consumption may be expected. Approximately 46.5 per cent. of the vegetable oil and fat consumed in this coun-

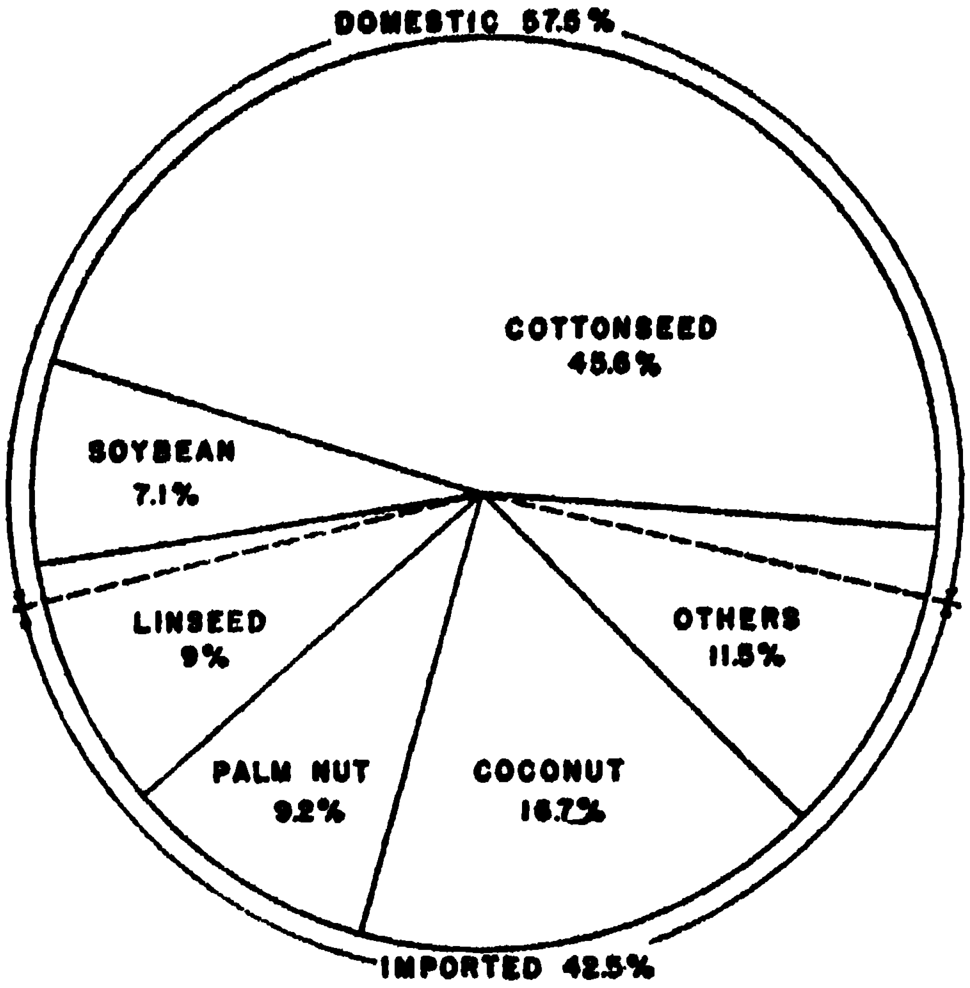

FIG. 1. PRIMARY OILS AND FATS CONSUMED IN U. S. FACTORIES—1938. AN ANALYSIS OF THE SOURCES OF UNITED STATES VEGETABLE OILS AND FATS.

try was derived from cotton seeds, 16.7 per cent. was derived from coconuts, 9.2 per cent. from oil palm nuts, 9 per cent. from flax seeds, and 7.1 per cent. from soybeans (Fig. 2). The remaining 11 per cent. of our vegetable oil and fat was derived from tung tree nuts, corn, peanuts, rape seeds, perilla seeds, castor beans, babassu palm nuts and a number of other oil-producing species. Especially to be noted in this list are coconuts, oil palm nuts, flax seeds, and among the minor sources, tung tree nuts, castor beans and babassu palm nuts, since our entire supplies of the oils and fats derived from these plants are imported. Surprisingly enough, the United States also imports small quantities of cotton seed, corn and peanut oil. Of the three and one half billion pounds of vegetable oils and fats consumed in our factories in 1938, almost one half, or about one and one half billion pounds, was imported. These oils and fats come to us principally from the Philippine Islands, the Netherland East Indies, China, West Africa, Argentina, Brazil and Japan. The fact that we are now so dependent upon outside sources for vegetable oils and fats must be considered in charting the course of American foreign diplomacy and agricultural economy.

Thus far, despite the present wars, our vegetable oil trade has not been seriously affected. Our African supplies have been partially cut off, but since they were already becoming less significant with the shift of oil palm production to Sumatra, no shortages have been created. Our imports of tung oil and, secondarily, peanut oil, from China have also been curtailed. However, this curtailment has not been too serious, since Hong Kong is still an open port and even the Japanese are not too unwilling to act as middlemen. The only result of the European war thus far has been some allocation of trade because certain oil-bearing raw materials which formerly went to England, Belgium and the Netherlands for processing are now being shipped directly to the United States.

In planning for future supplies of vegetable oils and fats, particular attention must be paid to Southeastern Asia and the adjacent East Indies. Over two thirds of our imports, or almost one third of all the vegetable oils and fats consumed in this country, come from that part of the world. Rubber and tin are

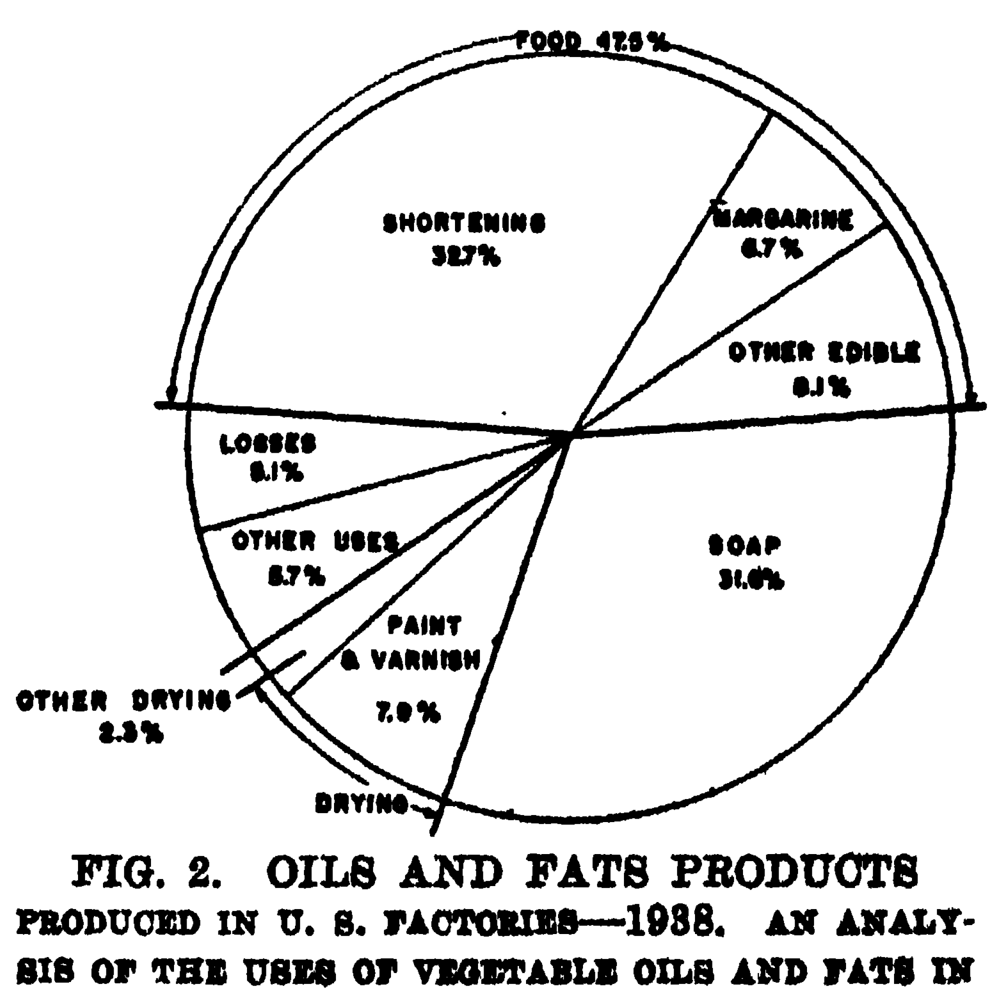

FIG. 2. OILS AND FATS PRODUCTS PRODUCED IN U. S. FACTORIES—1938. AN ANALYSIS OF THE USES OF VEGETABLE OILS AND FATS IN THE UNITED STATES.

not the only raw materials which should influence the course of our diplomacy in the Far East. Japanese aggression could become especially serious if the Philippines, from which we obtain 100 per cent. of our coconut oil, were cut off from trade with us.

Two countries in South America contribute substantial amounts of vegetable oils and fats to the United States. From Argentina we obtain about two thirds of our linseed, and from Brazil we receive cotton, peanut, castor and babassu oil. Several other countries in South and Central America are potential sources of oil. If Southeastern Asia and the East Indies were cut off from the United States trade, we should have to depend upon Latin America for the oils and fats of tropical plants. This potentiality of our Southern neighbors might well be utilized in our present "hemispherical solidarity" campaign, since any effort on our part toward encouraging production of vegetable oils and fats in South America would be of mutual benefit. Admittedly, it would take a number of years to establish this trade, but if we are preparing for any eventuality, it might be well for us to start now.

The question finally arises: How would this nation fare if all these sources of vegetable oils and fats were cut off from us by war or blockade? The immediate result, especially if this severance were sudden, would be an acute and dangerous shortage for an indeterminate period. The ultimate result would depend upon our ability to make shifts in our agricultural economy, to develop substitutes and to make technological changes. All this presupposes that we would not be content to lower our living standards to those which exist on Continental Europe.

Let us first consider our ability to increase our domestic production of vegetable oils and fats. Physical conditions, chiefly climatic, make it impossible for us to grow the coconut, oil and babassu palms, which, together, now supply us with about one fourth of all our

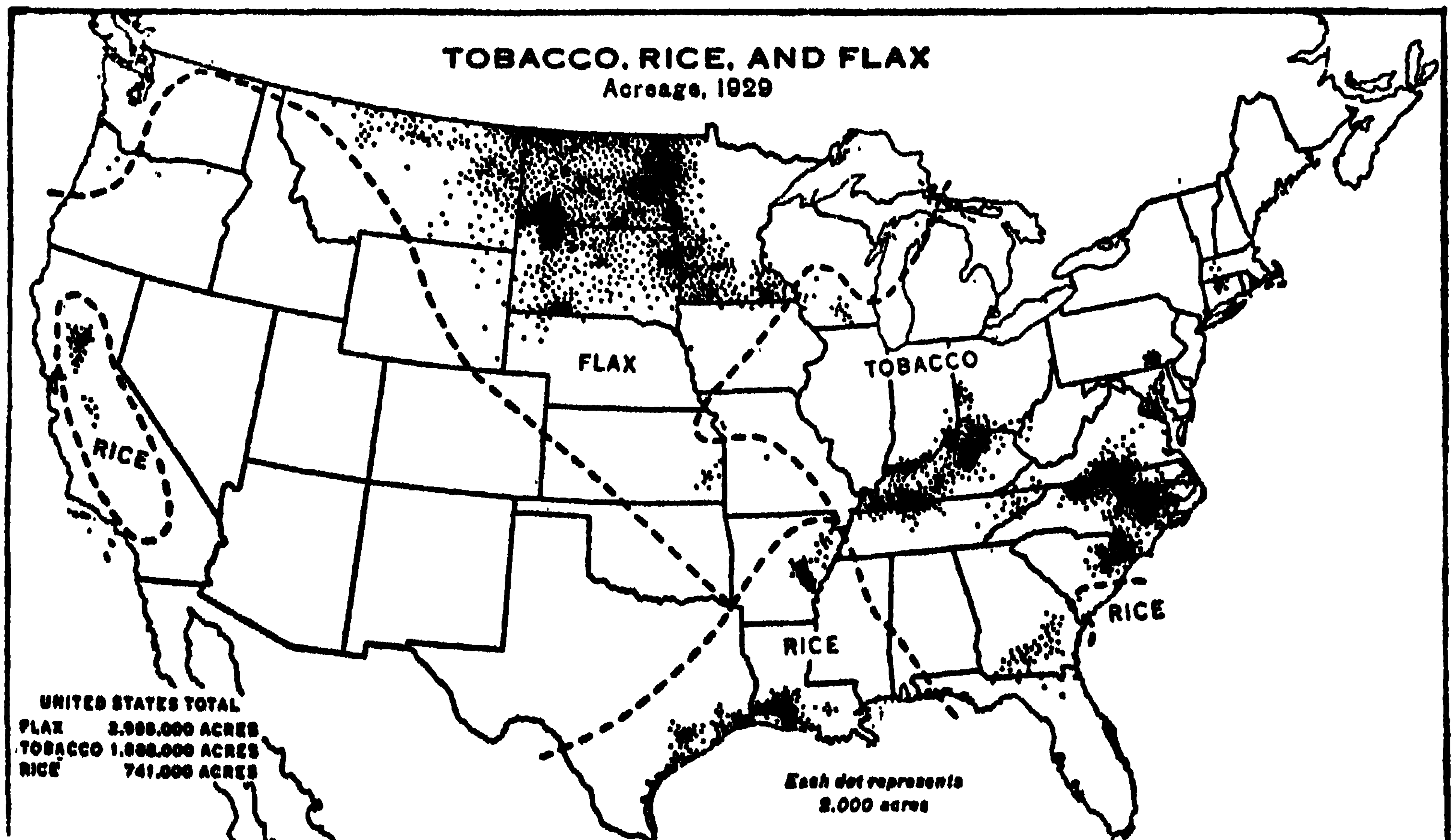

FIG. 3. FLAX ACREAGE, 1929*

THE SPRING WHEAT BELT IS OUR GREAT PRODUCING AREA.

* Figures 3, 4, 5 and 6, are printed through the courtesy of the U. S. Department of Agriculture.

vegetable oils and fats. All other significant oil-producing plants, cotton, flax, tung, soybean, corn, castor bean, etc., can be raised successfully in this country. Despite this, we now import vegetable oils and fats derived from all except one of the plants just listed. Thus, any campaign for self-sufficiency would, perforce, have two objectives: first, to become independent of outside sources for the oils and fats of the plants we can raise; and, second, by utilizing native plants, to balance the deficit which would exist because we can not grow oil-producing palm trees.

The leading native source of vegetable oil is cottonseed. Better methods of expression and complete use of all our seed would easily make up for the small amount of cottonseed oil which is imported. However, under existing cotton prices, a great extension of acreage, sufficient to make up our deficit, seems improbable. It might be stated at this point that a variety of cotton which produces little lint and a seed which has a high oil content has already been developed. However, to make this type of plant profitable, oil prices would have to rise considerably.

Next on the list of oil-producing plants which are grown in the United States is flax, whose seed (linseed) is the leading source of drying oil. At present we supply about one third of our need. Most of this comes from the grain lands of the Dakotas (Fig. 3). In view of our large annual wheat surplus, it would seem that the simplest solution to the problem would be to turn wheat acreage over to flax. However, flax is a difficult plant to cultivate and harvest, and, in addition, is much more subject to losses through vagaries of weather, weed growth, insect pests and blight than is wheat, so that even now, in spite of high protective tariffs, it is not a popular crop. Perhaps some form of government crop insurance to make it a less speculative crop would encourage increased production. Some small subsidization might also be necessary. If these measures were instituted, flax acreage might be increased to about the necessary 4,000,000 and self-suffi-

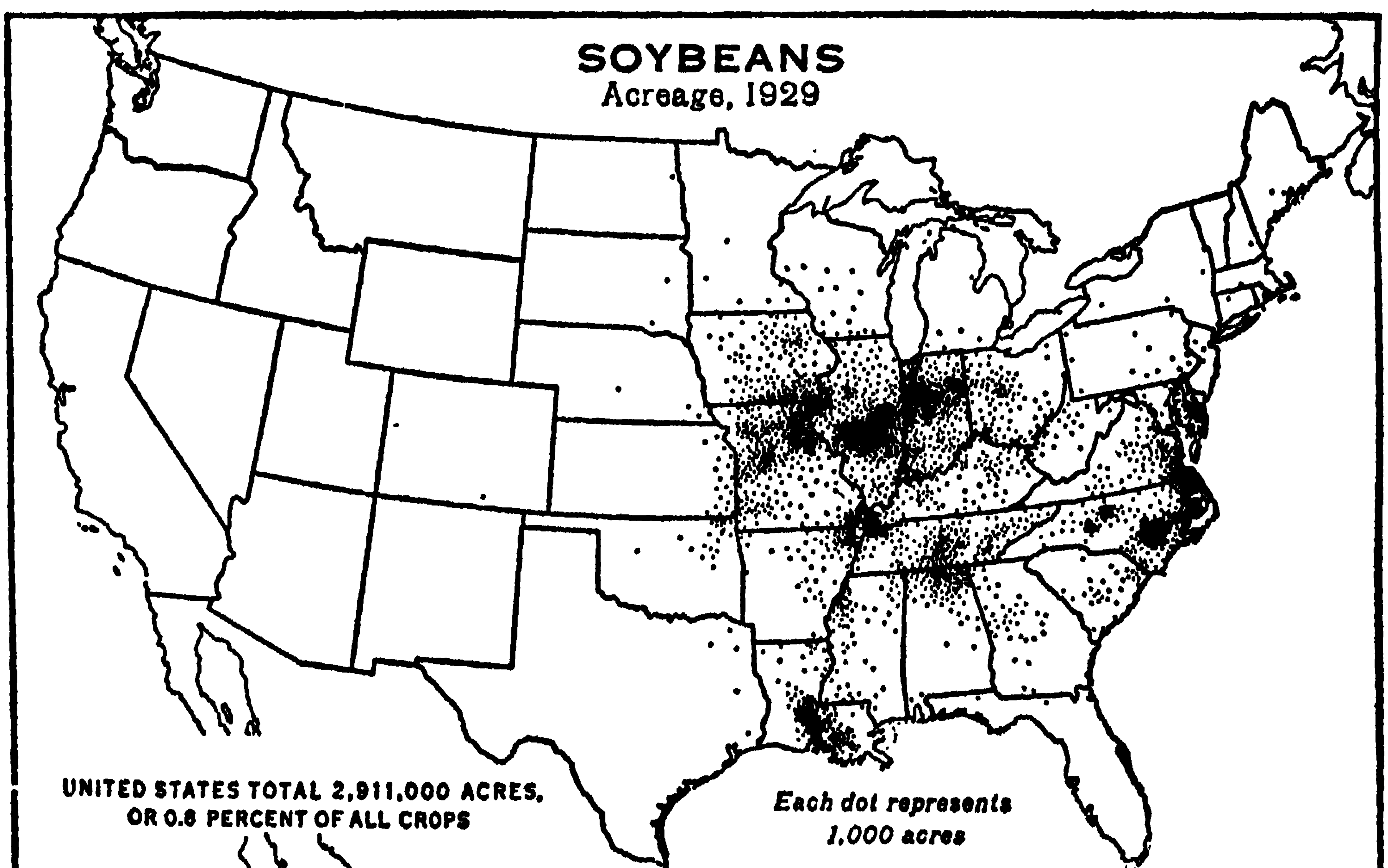

FIG. 4. SOYBEAN ACREAGE, 1929

SOYBEANS ARE PRODUCED IN OUR CORN BELT AND MANY AREAS IN THE SOUTH.

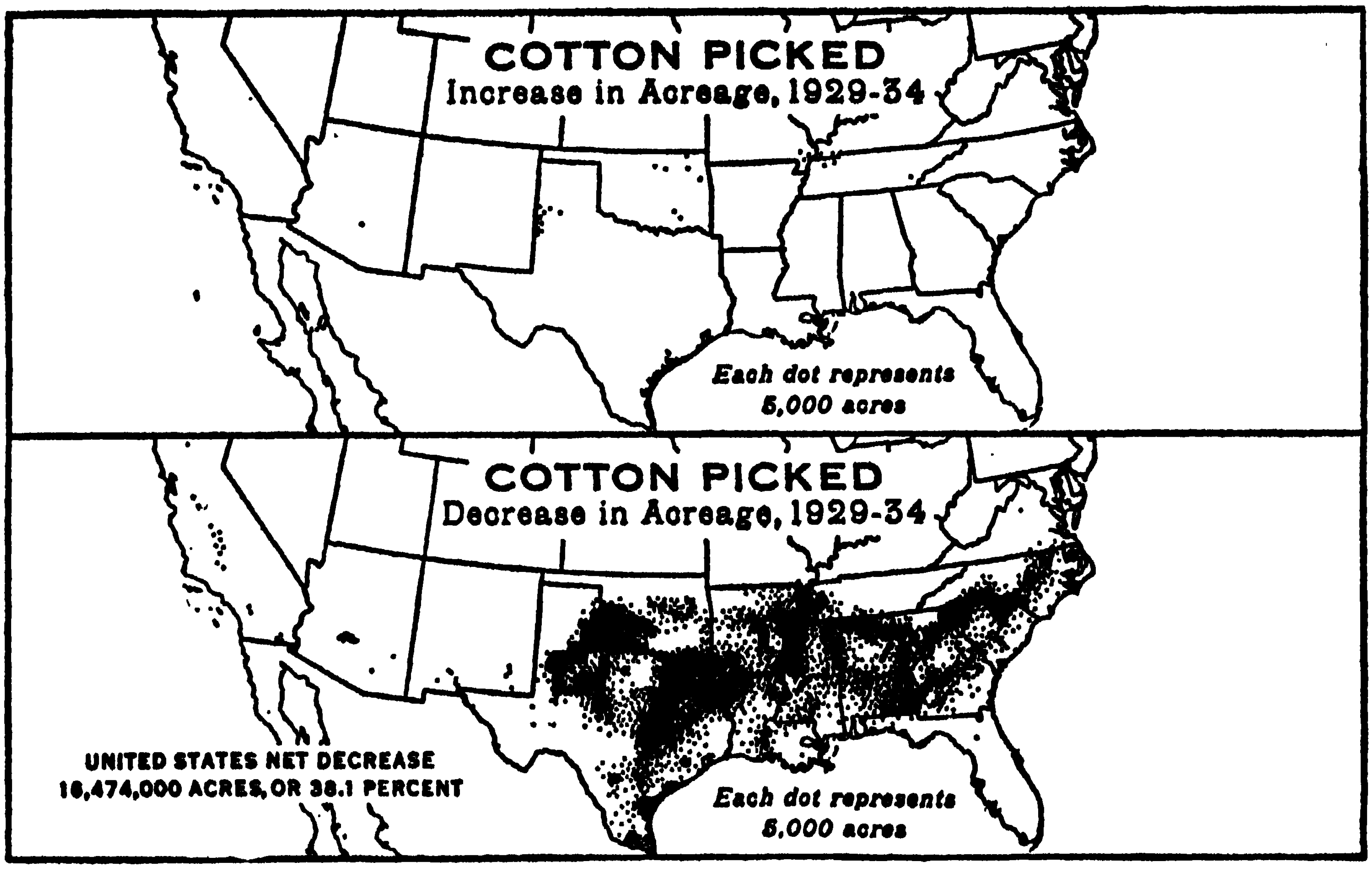

FIG. 5. CHANGE IN COTTON ACREAGE, 1929–1934

PERHAPS SOME OF THE LAND TAKEN OUT OF COTTON PRODUCTION MIGHT BE DEVOTED TO OIL-PRODUCING CROPS.

ciency be attained. The recent development of strains of flax producing good oil seed and fiber suitable for linen (also a need in this country) will probably be an added incentive toward more flax production.

A secondary source of drying oil is the tung tree. The United States imports

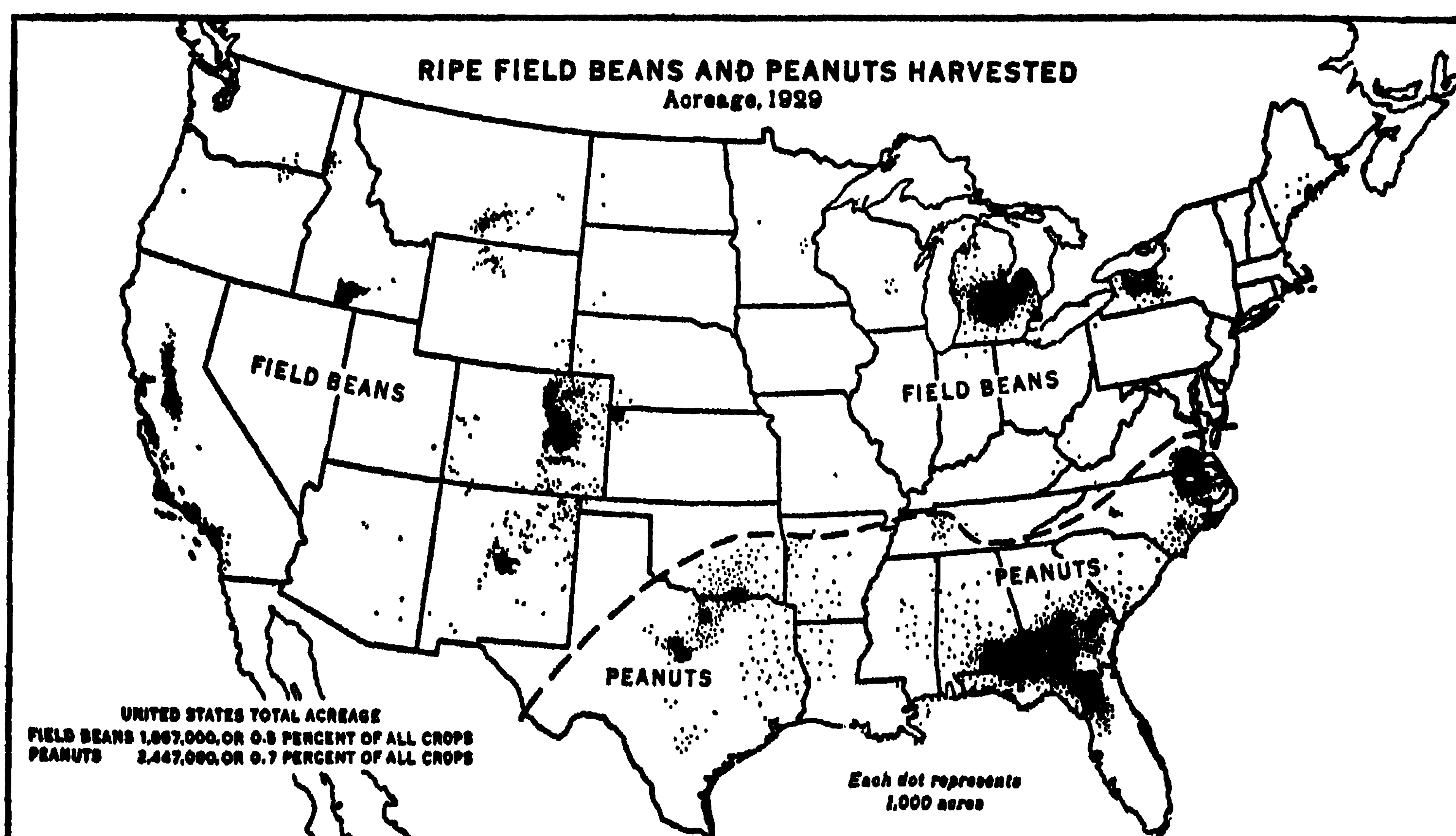

FIG. 6. PEANUT ACREAGE, 1929

PEANUTS ARE AN EXCELLENT SOURCE OF EDIBLE OIL.

85 per cent. of its need of this important paint, lacquer and waterproofing material from China. Tung oil also enters into the manufacture of such products as linoleum, oil cloth, brake lining and inks. Since the Chinese supply was uncertain even in pre-war years, tung tree orchards were started in our Far South (southern Mississippi, Alabama, Georgia and northern Florida) about forty years ago. Today, the lessons of production having been learned, the United States is well on the road to self-sufficiency, a goal which might well be reached in the next ten or fifteen years if the present rate of increase is maintained. For the time being, however, we are still dependent upon China.

Since both drying and edible oil can be obtained from the soybean, that source of oil has unique value. So great are the potentialities of the United States for soybean production that we already supply all our own soybean oil needs with ease. Large areas in the Corn Belt are almost ideal for its production. The great surplus of corn in recent years would seem to indicate that this corn land could easily, and even more profitably, be turned to the soybean, which also has the advantage of being a leguminous crop. Another large region of the United States which is suitable for soybean production is the South, where it is now grown mainly as a forage crop (Fig. 4). The 16 million acre reduction in cotton acreage in this country in recent years has certainly made land available for raising soybeans (Fig. 5). If soybean production could be tripled, at least one third of our deficit of vegetable oils and fats could be overcome.

Two other crops which might be produced in increasing amounts in our South are the peanut (Fig. 6) and castor bean. Peanut oil is an excellent edible oil and could well take the place of either the olive or cottonseed as a source of salad oils and in margarine production. By increasing our acreage only one fourth we could become self-sufficient. Even a twofold or threefold acreage increase should not be difficult. Castor bean oil is an important source of lubricants, particularly for use in aviation, and thus has special strategic importance. Our need could easily be supplied by domestic production.

The case of corn as a source of vegetable oil is a puzzling one. This country has always produced a tremendous quantity of corn, very little of which, however, is utilized as a source of oil. During the first World War corn oil entered the market to make up for the deficiency in fats and oils which existed at that time. Admittedly, this oil was for a while inferior to other types, but was very soon brought to a desirable quality standard. Yet after the war, it almost dropped out of sight in spite of extensive advertising campaigns. Perhaps another effort to educate the American housewife to its desirability would be the most effective wedge toward its increased use. Corn oil, along with soybean and peanut oil, might be the answer to the problem of making this country independent in its supply of edible oils and fats.

Although it is physically possible for the United States to become free of foreign sources of vegetable oils and fats, there are a number of "ifs" and "buts" which would make the freeing process a long-time affair. Basically, most of the difficulties are centered in the fact that the education of both producer and consumer would require years to complete. It is also true that the farmer has always been conservative in introducing new crops or making sharp changes in his cropping system. Though these changes may be brought about more quickly by bounties, subsidies, or tariffs, all these measures would result in increased prices, which, in turn, might result in a

decreased demand. Such a condition would be incompatible with our goal of butter and guns.

To tide us over a transitional period as smoothly as possible, substitutes for vegetable oils and fats would have to be utilized. Perhaps the best of these substitutes is animal oils and fats of which, fortunately, the United States produces a great surplus. Each year, until the present European war, this country exported over a billion pounds of lard. Much of this is now accumulating in warehouses.

There are a number of objections to permanently substituting animal oils and fats for vegetable oils and fats. Briefly, these are: their non-drying quality; their lower desirability for edible purposes; and their undesirability for soap-making purposes. If our acreage of oil-producing plants were gradually increased, our output of animal oils and fats would automatically decrease at a greater rate, since the acreage of forage crops would become smaller. Thus the present problem of over-production of animal oils and fats would also be partially solved. It should be emphasized, however, that it would be our animal oils and fats which would best serve to carry us through any period of shortage.

Other possible substitutes for vegetable fats and oils are mineral oils and chemically produced materials which perform the same duties as oils and fats. Even though mineral oils are a potential raw material source of certain oils and fats which could take the place of vegetable oils and fats (an artificial tung oil has already been perfected), the uncertainty of future supplies and their importance in a war economy makes them unlikely substitutes. In the last few years chemically produced detergents, soap substitutes containing no oils or fats, have received considerable attention and may prove to be a valuable asset, since soap-making consumes 20 per cent. of our vegetable oils and fats. At the present time, small amounts of detergents are used as soap substitutes. Here again, the time factor becomes an element to be considered, for the construction and installation of the proper apparatus and machinery can not be an overnight process.

It thus appears that, if, in this country, we expect to have and to continue to have our guns along with our butter, we must be prepared for certain eventualities. At present, the most serious threat upon our supplies of vegetable oils and fats lies in possible Japanese aggression in the Far East. This threat would be especially serious if the Philippines were lost, because it would certainly be followed by a period of acute shortage and technological change. If we did not prevent such an eventuality, our best opportunity to prepare for its consequences would lie in the development of South American sources, and some changes in domestic production. Of course, even the present or projected South American supply could be cut off, for example, by political unrest or by German economic penetration. Unless we are prepared to go through a rather painful readjustment period of from five to ten years, we must either be ready to prevent certain eventualities or must begin to prepare now for complete national self-sufficiency in vegetable oils and fats.

THE CREATIVE YEARS: MEDICINE, SURGERY AND CERTAIN RELATED FIELDS

By Dr. HARVEY C. LEHMAN

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DURING what years of their lives are pioneer thinkers in medicine, surgery and public sanitation most likely to make their greatest contributions to the advancement of their fields, advances which will be regarded by later generations as priceless boons to humanity? In previous articles[1] the fact has been emphasized that generalizations with reference to man's intellectual productivity at various chronological age levels are sometimes based upon one or a very few exceptional cases. Impressionistic judgments based upon so-called "illustrative cases" are frequently fallacious. The general picture of man's creativity at successive chronological age levels can not be obtained by the use of "illustrative cases," unless it is definitely known that the cited cases represent a well-selected sampling. Therefore, the critical student should always ascertain, if possible, whether the citations which are submitted as "proof" are really fair and typical and not outstanding exceptions.

Nor do means and medians yield a very informative picture of the relationship between chronological age and man's creativity. The creative years may be envisaged best not by reference to "illustrative cases" which may have been obtained by inadequate sampling or by the use of a simple numerical average, which may hide as much as it reveals, but rather by study of age-curves (or statistical distributions) which reveal the relative productivity of all age groups.

It is the present writer's thesis that many of the studies heretofore published have tended to present a distorted picture of man's creativity. These earlier studies have been honest, in so far as conclusions which are based upon very limited data can be honest, and they have been interesting. But they have been analogous to the lawyer's one-sided plea. Some writers, for example, have presented an apparently strong case for youth; others have made a special plea for the aged. When controversy rages, a middle position, though perhaps less interesting, is likely to be more tenable than is either extreme point of view.

Careful study of the relative productivity of the various age groups involves among other things: (1) isolation of the most important contributions, (2) identification of the contributors, (3) knowledge of when the contributions were made and (4) knowledge of the exact birth and the death dates of the contributors. With the foregoing information it becomes a routine task to ascertain for each age group the average number of contributions that should be placed to its credit. The resultant averages should reveal clearly the age groups that have been most productive. One exception to this last statement should be mentioned. It is quite impossible to know the amount of time that must often have elapsed between the birth of a great idea and its public announcement. Obviously, the date of announcing an invention or a discovery does not enable us to know the chronological age at which the contribution was actually made. We can know only that the contributions

[1] (a) H. C. Lehman, THE SCIENTIFIC MONTHLY, 43: 151–162, 1936. (b) J. B. Heidler and H. C. Lehman, *The English Journal* (College Edition), 155: 294–304, 1937. (c) H. C. Lehman, THE SCIENTIFIC MONTHLY, 45: 65–75, 1937. (d) H. C. Lehman, *The Research Quarterly*, 11: 3–19, 1938. (e) H. C. Lehman and D. W. Ingerham, THE SCIENTIFIC MONTHLY, 48: 431–443, 1939.

that are to be discussed herein occurred *not later* than the chronological age to which they are credited.

The problem of evaluation presents a second difficulty. How are the fruits of genius to be evaluated? Does any individual possess the technical knowledge requisite for identifying the most important contributions that have been made in the fields of medicine, surgery, sanitation and the like? Would it not be presumptuous for the layman to attempt to evaluate the contributions which have been made in these highly specialized fields? Fortunately, in many instances, the task of evaluation is one that has already been performed by unintentional collaborators—by specialists in the various fields of endeavor. In one sense the present study is therefore merely a by-product of previous studies that have been made by recognized experts, who published their evaluations under their own names and who therefore must have felt their professional responsibility for making just evaluations.

The utilization of appraisals that have been published by well-known experts is desirable for still another reason. It is probable that most of the present writer's unwitting collaborators made their appraisals without thinking at all about the problem of age differences. Evaluations thus made are all the more useful for the study of age differences in productivity, since they are likely to be impartial judgments in so far as the age factor is concerned.

For example, in a book entitled "The Fundamentals of Bacteriology"[2] Professor C. B. Morrey presents a chronology of the contributions which he regards as the foundation stones of the science of bacteriology. Morrey lists not only the contributions but also the names of the contributors and the years during which each of the various advances was either made or first published. With this essential information at hand, the present writer undertook the task of finding the birth and the death dates of the various contributors. Some of these dates were found easily, some were found with difficulty, and some of them could not be found at all. The fact that some of the birth and death dates are unrecorded suggests that brilliant achievements are not always recognized as such by an individual's contemporaries. If the noteworthy contributions had been appraised immediately at their true worth, surely the birth and the death dates of the contributors would have been recorded!

Fig. 1 presents the results obtained by study of Morrey's chronology, namely, the chronological ages at which 50 outstanding discoveries were made by 41 pioneers in the field of bacteriology. Since Fig. 1 presents the *average* num-

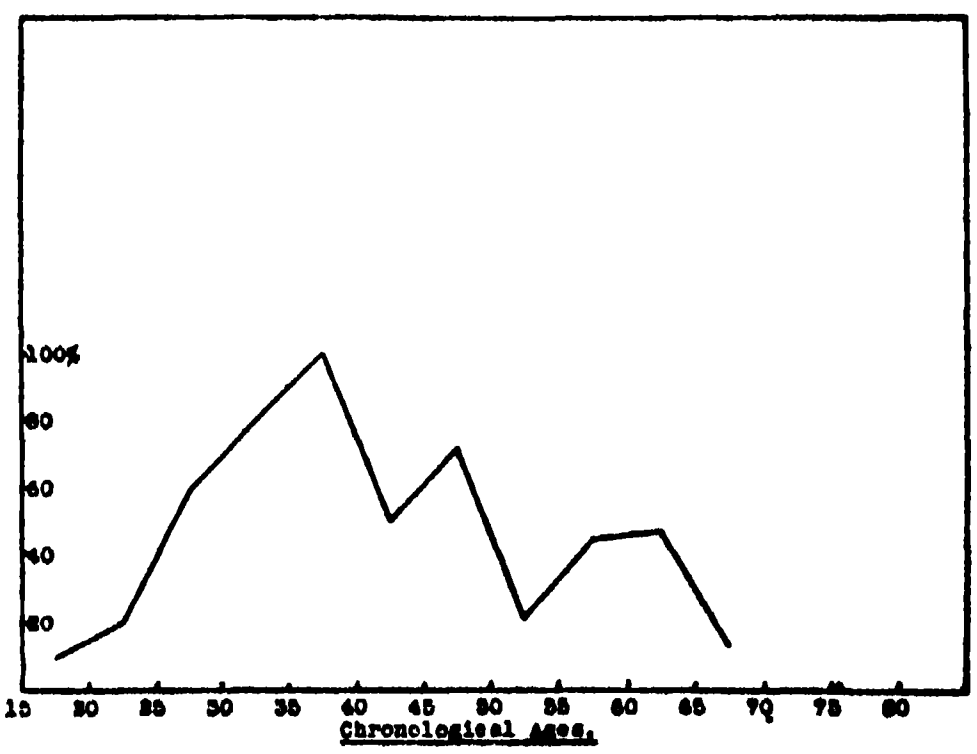

FIG. 1. AVERAGE NUMBER OF CONTRIBUTIONS TO BACTERIOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 41 INDIVIDUALS WHO MADE 50 CONTRIBUTIONS.

ber of contributions at each chronological age level, this figure makes proper allowance for the fact that more of the contributors were alive at the younger than at the older age levels. Thus, in obtaining the data set forth in Fig. 1, it was found that, at the age interval 35 to 39 inclusive, the average number of contributions from each individual was 0.050, whereas,

[2] C. B. Morrey, "The Fundamentals of Bacteriology." Third Edition. Philadelphia and New York: Lea and Febiger, 1923. Pp. xiii + 344. (See the chronology on bacteriology on pp. 33–36).

at the age interval 55 to 59 inclusive, the average had fallen to 0.022. In Fig. 1 the curve is so drawn as to be only 0.022/0.050 as high at ages 55 to 59 as at ages 35 to 39, thereby indicating that average productivity was only about two fifths as great at ages 55 to 59 as at ages 35 to 39.

If, regardless of the number of individuals that remained alive, the older age groups had contributed at the same average rate as did age group 35 to 39, the curve in Fig. 1 would have remained as high at the older age levels as it is at the age interval 35 to 39. Actually, the curve in Fig. 1 descends rather abruptly after attaining its peak at the age interval 35 to 39. Fig. 1 thus seems to reveal clearly and unmistakably that, in proportion to their numbers, men have made contributions to the science of bacteriology most frequently at ages 35 to 39, inclusive.

Let us see what has occurred in fields other than bacteriology. Fig. 2 presents the chronological ages at which 59 important works were first published by 54 noted physiologists. Data for the construction of Fig. 2 were obtained from Professor J. F. Fulton's "Selected Readings in the History of Physiology."[3]

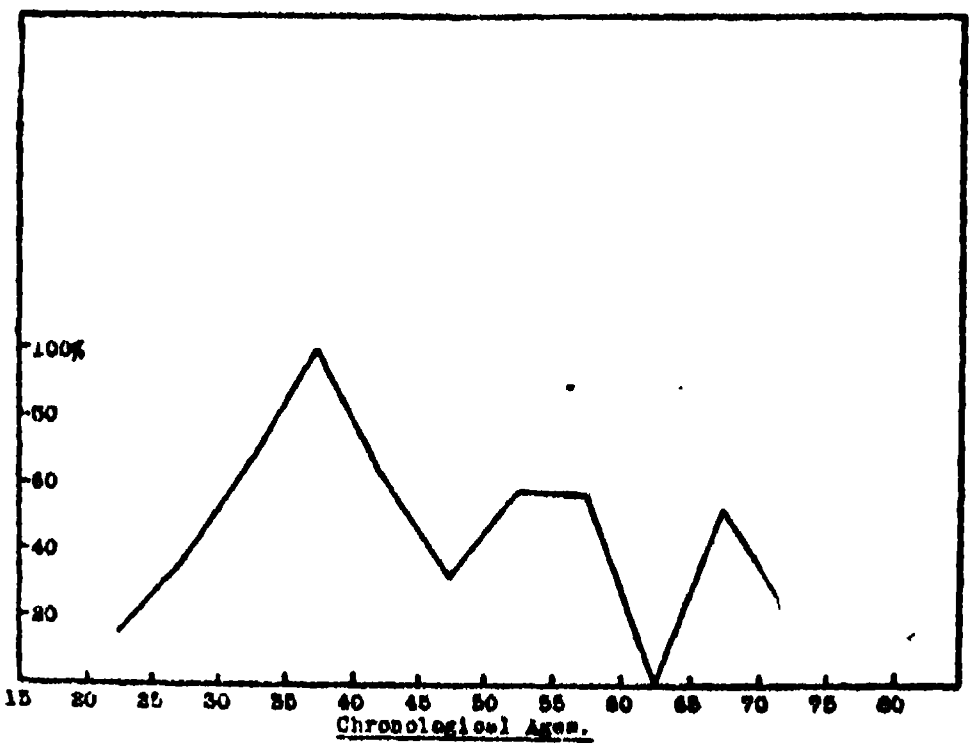

FIG. 2. AVERAGE NUMBER OF CONTRIBUTIONS TO PHYSIOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 54 INDIVIDUALS WHO MADE 59 CONTRIBUTIONS.

[3] J. F. Fulton, "Selected Readings in the History of Physiology." Springfield, Ill.: Thomas, 1930. Pp. xx + 317.

Professor Fulton presents not only the names of the contributors and their contributions, but also the birth and the death dates of the contributors and the year during which each of the several contributions was first published. Computation of average productivity at each chronological age level (see Fig. 2) was therefore a relatively easy task.[4] It is evident at once that Fig. 2 bears much resemblance to Fig. 1. In each of these curves a definite peak occurs at ages 35 to 39, inclusive, and beyond this age interval both curves exhibit marked declines.

A goiter chronology was found in Professor Robinson's "Syllabus of Medical History."[5] In the latter chronology Robinson endeavored to list fundamental contributions which have to do with either knowledge of, or the treatment of, goiter. Fig. 3 is based upon 52 such contributions that were made by 40 different individuals. In Fig. 3 it was necessary to include the works of both living and deceased contributors in order to obtain sufficient data to yield an age-curve. Despite this fact, the peak of the

[4] Since it is not possible to study the entire life work of individuals who are still living and achieving, Figs. 1 and 2 present data for deceased individuals only. For these the record is complete, and future research will probably change it only slightly, if at all. There is at least one other important reason for omitting the contributions of living individuals. The evaluation of contributions that are made by one's contemporaries is an extra-hazardous undertaking, even when the evaluations are made by experts. With the passing of time a better perspective is likely to be attained, and contributions can then be appraised at more nearly their real worth. Thus, the significance of Gregor Mendel's important paper on genetics was not fully realized until some years after Mendel's death. And the present writer has assembled data which seem to suggest that this was not an isolated instance. Often achievements which are hailed with acclaim by one's contemporaries are regarded as unimportant by a critical posterity. Therefore, unless otherwise stated, the graphs that are presented herein will be based upon the works of deceased individuals only.

[5] V. Robinson, "Syllabus of Medical History." New York: Froben Press, Inc., 1933. Pp. 110. (See p. 83.)

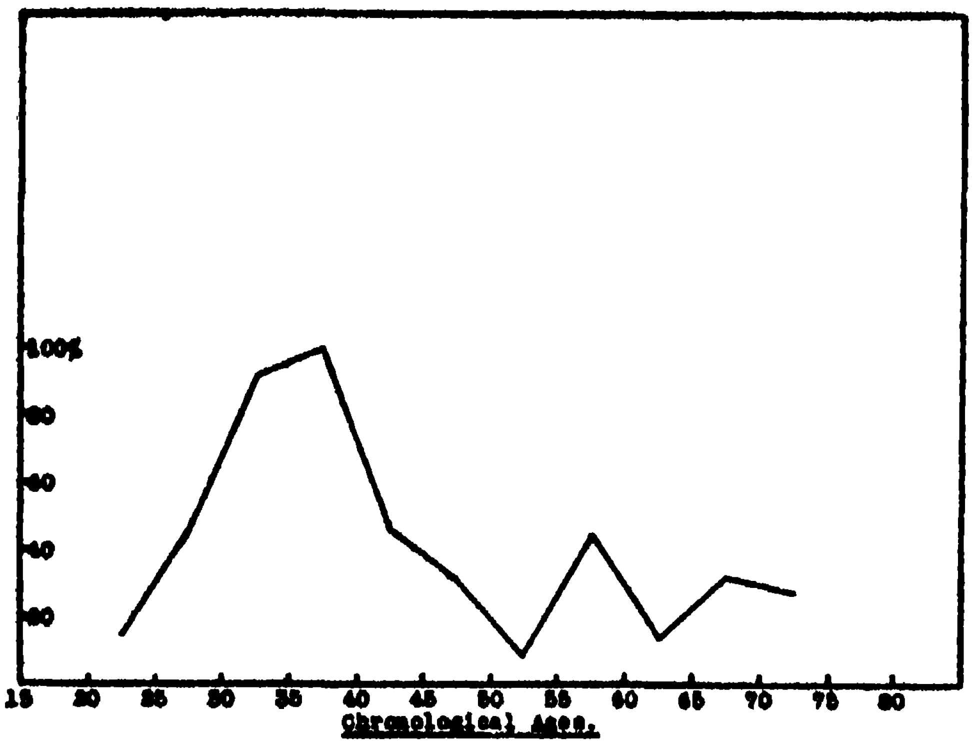

FIG. 3. AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL WHICH HAVE TO DO EITHER WITH KNOWLEDGE OF OR THE TREATMENT OF GOITER. THIS GRAPH PRESENTS DATA FOR 40 INDIVIDUALS WHO MADE 52 CONTRIBUTIONS.

curve is again attained at ages 35 to 39, and a sharp descent occurs thereafter.

Fig. 4 presents data for 216 contributions to the science of pathology which were made by 170 different individuals.

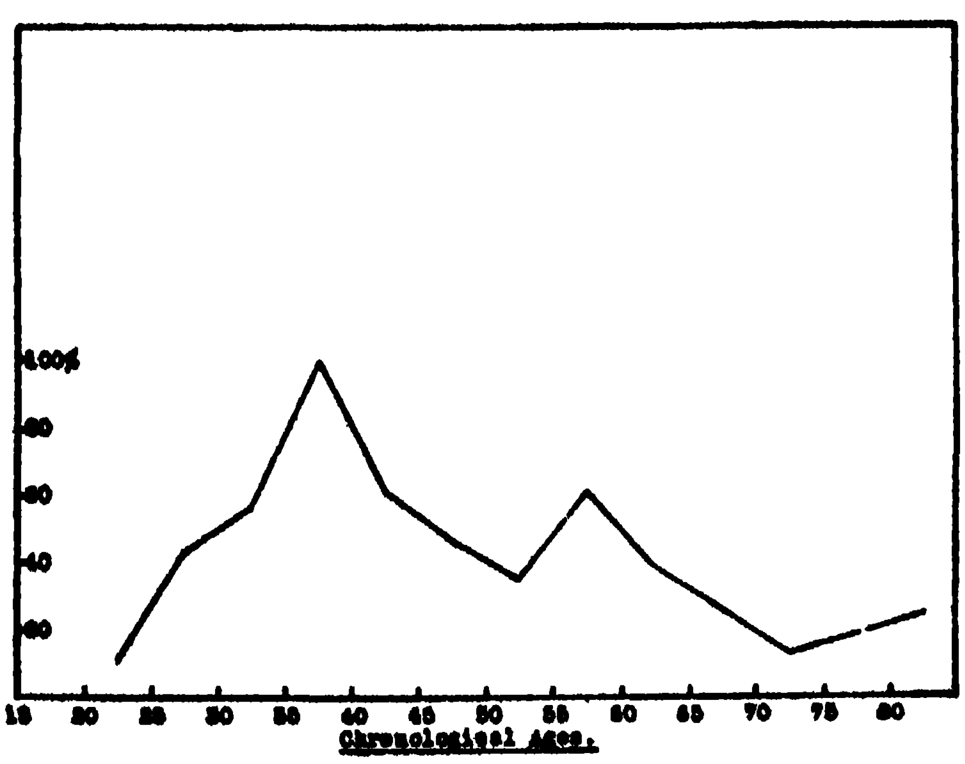

FIG. 4. AVERAGE NUMBER OF CONTRIBUTIONS TO PATHOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 170 INDIVIDUALS WHO MADE 216 CONTRIBUTIONS.

The list of pathological milestones was assembled and published by Professor E. B. Krumbhaar.[6] In Fig. 4 the peak which appears at ages 35 to 39 is even more narrow than are the peaks which are to be found in the three figures that precede Fig. 4.

Fig. 5 presents additional data from the field of pathology. The data for Fig. 5 were obtained from a book by Professor E. R. Long entitled "Selected Readings in the History of Pathology."[7] Although Fig. 5 presents data for only 30 contributions by 27 deceased individuals, it is of interest that this very select group

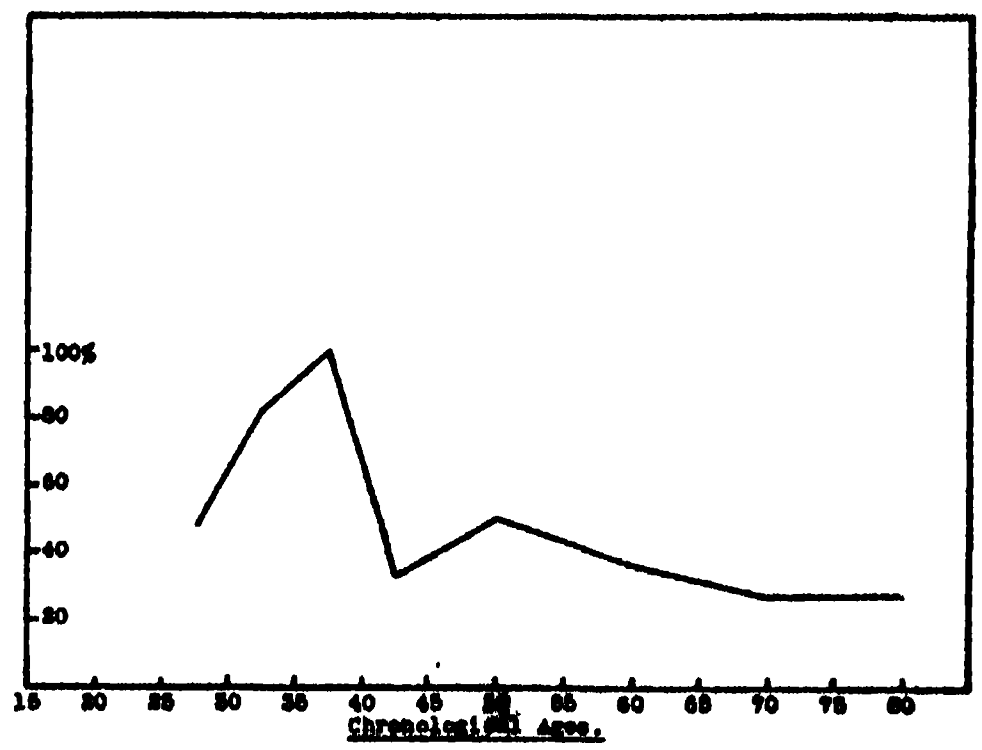

FIG. 5. AVERAGE NUMBER OF CONTRIBUTIONS TO PATHOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 27 INDIVIDUALS WHO MADE 30 CONTRIBUTIONS.

of cases yields a curve in which the peak occurs once again at ages 35 to 39, inclusive. It should perhaps be stated that Fig. 5 was smoothed from ages 40 to 80 inclusive by taking ten years, instead of five, as the unit. This procedure increases the number of cases in each age group. Irregularities are thus eliminated, and the general trend of the age differences is brought out more clearly.

Fig. 6 sets forth 89 advances in the science of anatomy which were made by 70 individuals. The contributions used in the construction of Fig. 6 were listed in F. H. Garrison's "An Introduction to the History of Medicine."[8] This lat-

[6] E. B. Krumbhaar (Editor), "Clio Medica: A Series of Primers on the History of Medicine." XIX, "Pathology," by E. B. Krumbhaar. New York: Paul B. Hoeber, Inc., Medical Book Department of Harper and Brothers, 1937. Pp. xvii + 206.

[7] E. R. Long, Editor: "Selected Readings in Pathology from Hippocrates to Virchow." Springfield, Ill.: Thomas, 1929. Pp. xiv + 301.

[8] F. H. Garrison, "An Introduction to the History of Medicine." Fourth Edition. Philadelphia and London: W. B. Saunders Company, 1929. Pp. 996. (A chronology of medicine and public hygiene is given on pp. 809 ff.)

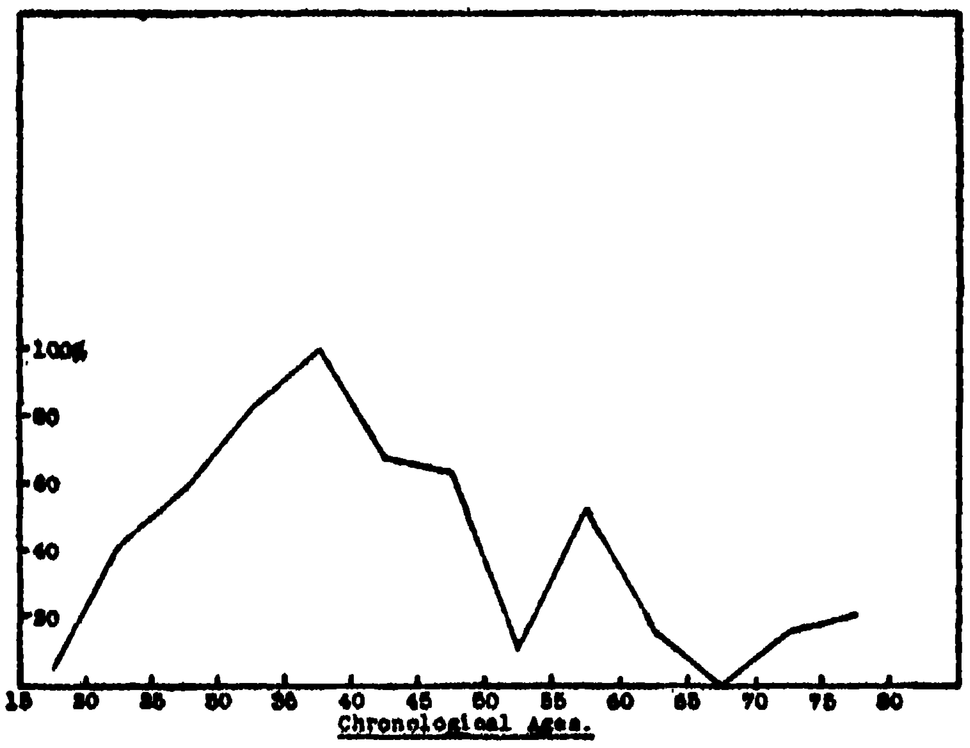

FIG. 6. AVERAGE NUMBER OF ADVANCES THAT WERE MADE IN ANATOMY DURING EACH FIVE-YEAR INTERVAL OF THE SCIENTISTS' LIVES. THIS GRAPH PRESENTS DATA FOR 70 INDIVIDUALS WHO MADE 89 CONTRIBUTIONS.

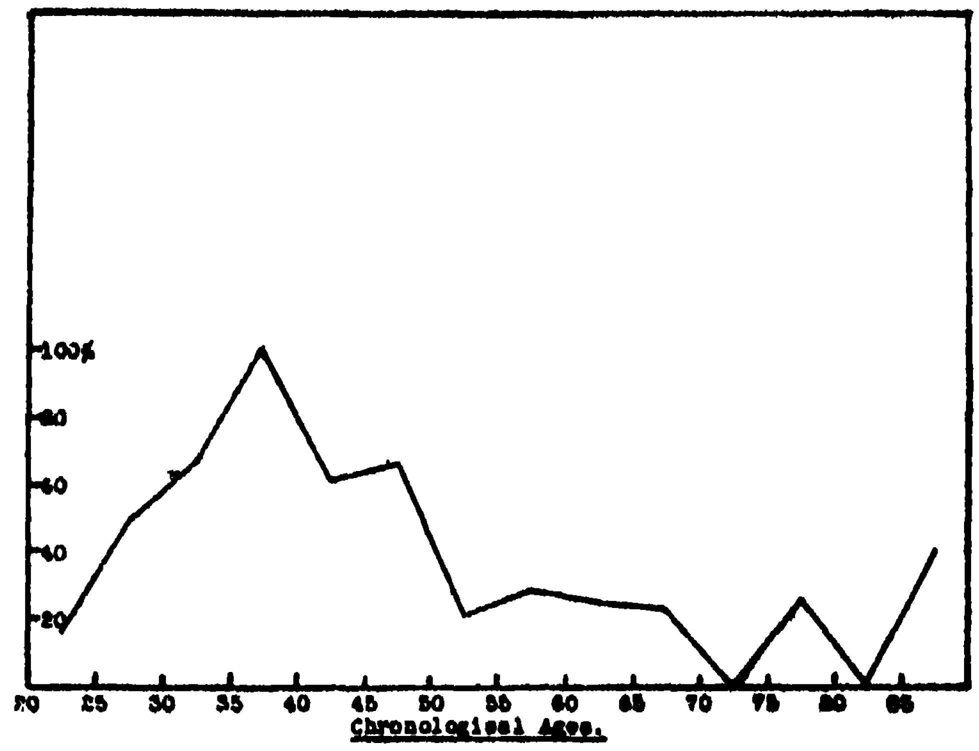

FIG. 7. AVERAGE NUMBER OF MEDICAL DISCOVERIES AND INVENTIONS THAT WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 159 INDIVIDUALS WHO MADE 188 CONTRIBUTIONS.

ter book contains an extensive chronology of medicine, broadly defined, and public hygiene. It will be noted again that Fig. 6 does not differ very greatly in general outline from the figures which have preceded it.[9]

Fig. 7 is based upon 188 medical discoveries and inventions that were made by 159 individuals. The data for this figure were found in B. J. Stern's "Social Factors in Medical Progress."[10] Stern presents a long list of multiple but independent discoveries and inventions in the field of medicine. Stern assembled his list in an attempt to discover whether inventions and discoveries in medicine would not have been made irrespective of the individuals who are now heralded as great innovators. On the basis of his extensive researches Stern asserts boldly that discoveries and inventions depend largely upon antecedent contributions and cumulative social gains. He believes that the alleged genius is largely the product of his environment, the instrument through which an idea or a creation receives expression. Stern therefore insists that practically the same progress would have been made in medicine if any or all of the popularly recognized research heroes had never lived. Whether the validity of Stern's contention be granted or denied, Fig. 7 and the other graphs that are presented herein certainly suggest that chronological age is a very important factor in medical progress.

Fig. 8 is based upon 97 contributions to surgery which were made by 73 individuals.[11] It should perhaps be mentioned at this point that the present article deals not at all with the individual surgeon's technical or diagnostic skill but with recognized advances in the field of surgical knowledge and practice. It is quite possible that a surgeon's own skill may reach its peak later in life, but that his important contributions to his profession are more likely to occur as indicated in Fig. 8.

The data for Fig. 8 were obtained from F. H. Garrison's "An Introduction to the History of Medicine."[12] Although

[9] By identifying in Garrison's chronology those contributions which have been of primary importance to the science of anatomy, Dr. Rush Elliott, of Ohio University, gave the present writer expert assistance in this phase of the present study. Thanks are expressed herewith.

[10] B. J. Stern, "Social Factors in Medical Progress." New York: Columbia University Press, 1927. Pp. 136. (See pp. 11 *ff.*)

[11] Dr. D. H. Biddle, a practicing physician of Athens, Ohio, identified in Garrison's chronology those contributions which have to do primarily with surgery. The present writer is grateful for Dr. Biddle's able cooperation.

[12] F. H. Garrison, *op. cit.*

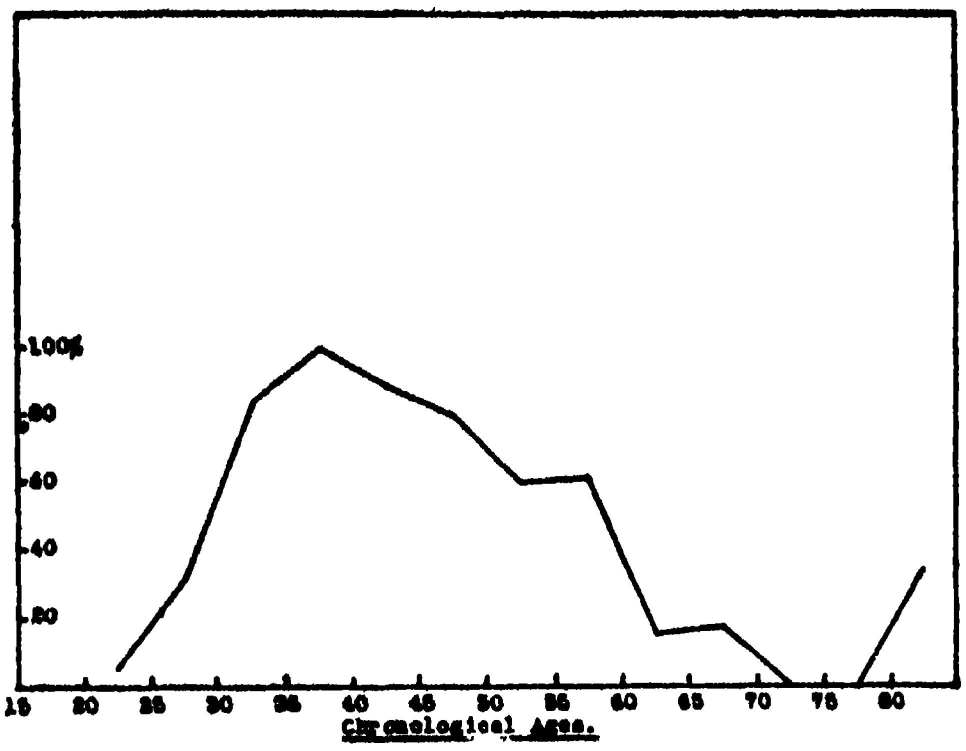

FIG. 8. AVERAGE NUMBER OF ADVANCES IN SURGICAL TECHNIQUE THAT WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 73 INDIVIDUALS WHO MADE 97 CONTRIBUTIONS.

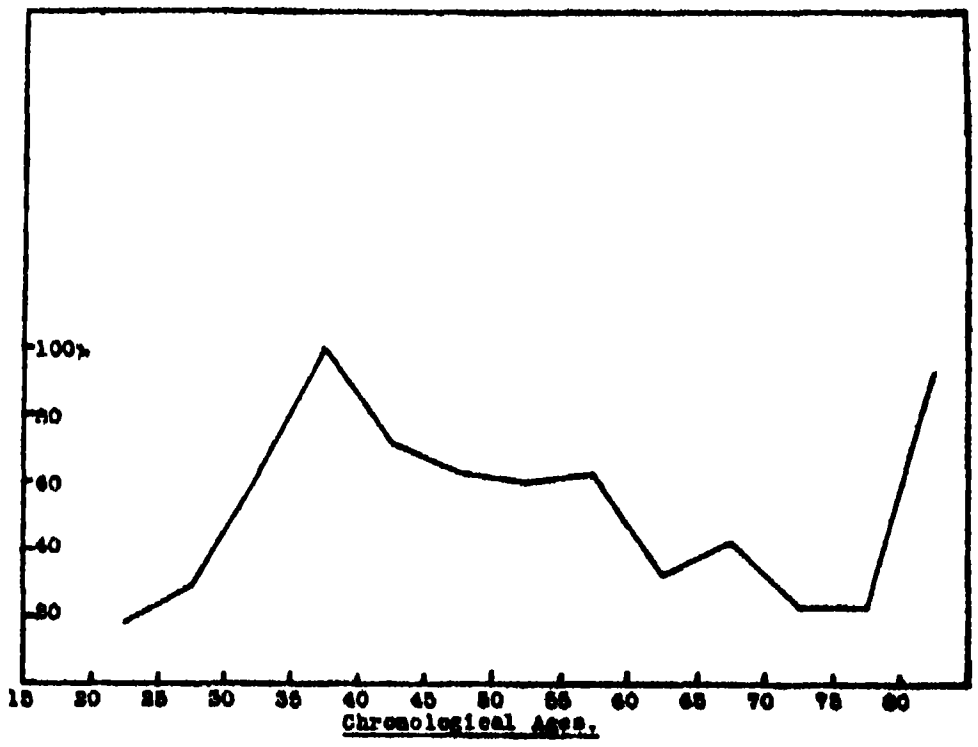

FIG. 9. AVERAGE NUMBER OF CLASSICAL DESCRIPTIONS OF DISEASES WHICH WERE FIRST PUBLISHED DURING EACH FIVE-YEAR INTERVAL OF THE WRITERS' LIVES. THIS GRAPH PRESENTS DATA FOR 102 AUTHORS WHO MADE 147 CONTRIBUTIONS.

the peak of Fig. 8 occurs at ages 35 to 39, it is worthy of mention that the decrement from ages 37 to 57 is less marked than are the decrements which are to be found at corresponding age levels in the curves which have preceded Fig. 8. This more gradual decline in Fig. 8 may possibly be due in part to greater delay in the announcement of surgical advances. Or it may be that, with advance in chronological age, contributions to surgery fall off more slowly than do contributions to the other fields that have been discussed herein.

Fig. 9 sets forth data for 147 classical descriptions of disease which were written by 102 different authors. These descriptions appeared in Dr. Ralph Major's book, "Classical Descriptions of Disease."[13] For the benefit of any who may wish to repeat the present study the following comments regarding the method of tabulating the data from Professor Major's book are included at this point. The dates of the classical descriptions of disease were utilized only when dates of first publication were available. *Post-mortem* publications were ignored whenever it was impossible to ascertain when such publications were written.[14] If Professor Major quoted from a translation or from some edition other than the first edition, the excerpt was counted only when the date of first publication was also available. If excerpts from a given source study appeared under more than one disease-heading in Professor Major's compilation, the source was counted as many times as excerpts therefrom were reproduced in Major's book. For example, age group 80–84 received five credits solely because at 80 G. B. Morgagni published a book entitled "De sedibus et causis morborum," which is quoted at five different places in Major's "Classical Descriptions of Disease." Similarly, age group 30–34 received three credits because at 30 James Hope published a book which is quoted by Dr. Major at three different places. In Fig. 9 the work of one man, G. B. Morgagni, is responsible for the rather marked rise in the curve at ages 80 to 84. Although age group 80 to 84 probably does not deserve sole credit for Morgagni's oft-quoted publication, sole credit was alloted to this age group because it seemed to the pres-

[13] R. H. Major, "Classical Descriptions of Disease." Springfield, Illinois. Thomas, 1932. Pp. xxvii + 630.

[14] The *post-mortem* publications were few in number. The discarding of some of these *post-mortem* contributions has probably not influenced the shape of the age-curves very materially.

ent writer that it would be highly subjective and unfair not to make this allocation of credit.

In general, it will be noted that Figs. 8 and 9 closely resemble each other. Both of these age-curves attain their peaks at ages 35 to 39. Both curves sustain themselves fairly well until age interval 55–59 is attained, and both exhibit a decided decrement beyond age 60. It is possible that Fig. 9 sustains itself so well at the upper-age levels because of the time-lag that may have sometimes occurred between the date of writing a classical description and the date of first publishing it. This latter hypothesis certainly accounts for the final rise of the age-curve in Fig. 9. It is well known that Morgagni spent many years writing his famous book. On the other hand, the relatively slow falling off of the curve in Fig. 9 (at ages 37 to 57) may be due in part to the fact that in many instances the classical description of a disease must be based upon prolonged experience with the disease in question.

Fig. 10 presents information regarding the discovery and introduction of 73 drugs and remedial agents employed in medicine. The 73 contributions were made by 44 persons. The chronology was obtained from Power and Thompson's "Chronologia Medica."[15] Fig. 10 attains its peak at ages 30 to 34, inclusive, thus providing the only instance in the present study in which an age-curve fails to attain its peak at ages 35 to 39.

In his book, "A Hundred Years of Psychology,"[16] J. C. Flugel has published a chronological table of what he describes as "some major events in the history of modern psychology." It was possible to obtain birth and death dates

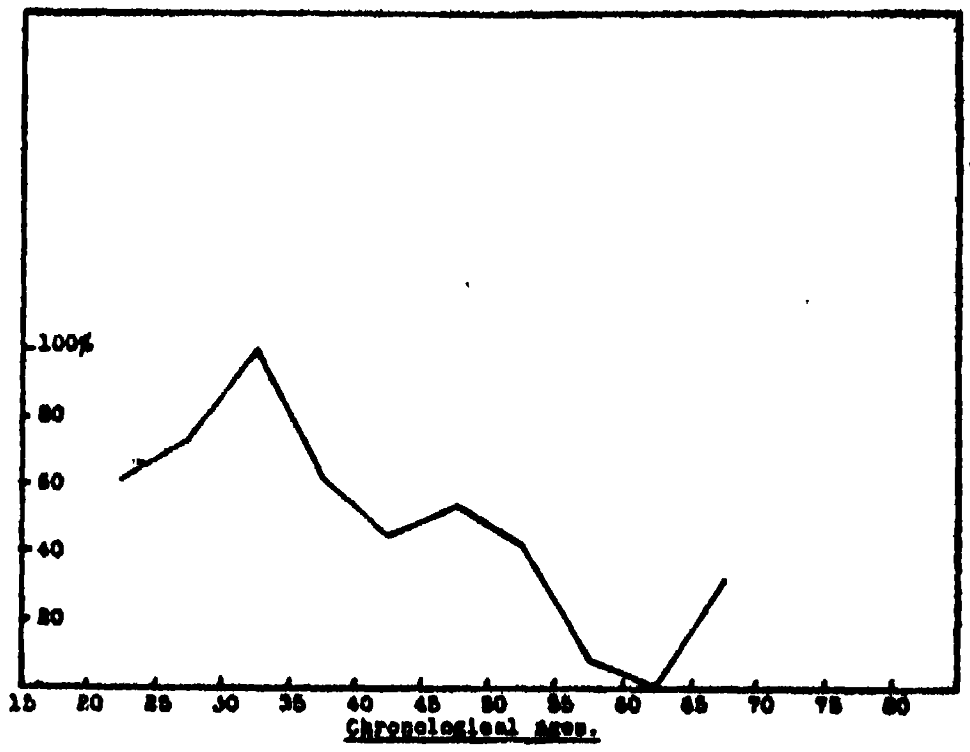

FIG. 10. AVERAGE NUMBER OF DRUGS AND REMEDIAL AGENTS EMPLOYED IN MEDICINE WHICH WERE EITHER DISCOVERED OR INTRODUCED DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 44 INDIVIDUALS WHO MADE 73 CONTRIBUTIONS.

for 50 deceased individuals who made 85 contributions. Fig. 11 reveals the resultant age-curve. The peak again occurs at ages 35 to 39, inclusive.

Fig. 12 presents 801 miscellaneous advances in medicine and in public hygiene which were made by 537 individuals all of whom are now deceased. The data were obtained from F. H. Garrison's book, "An Introduction to the History of Medicine."[17] Garrison's extensive list includes some of the contributions that were listed also in the other chronologies

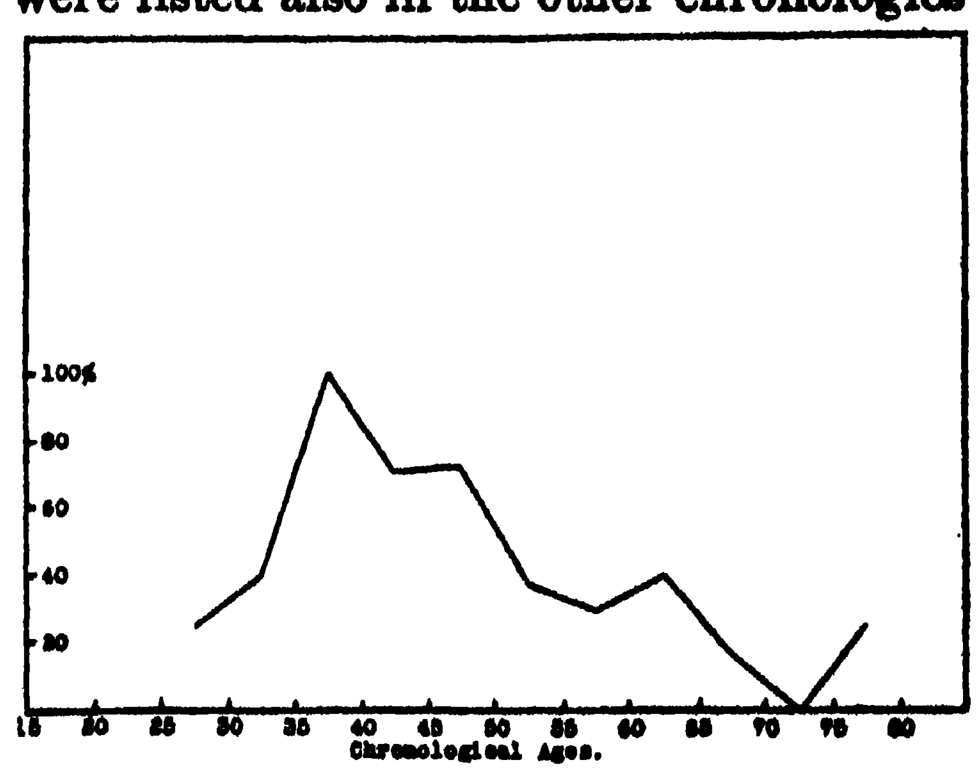

FIG. 11. AVERAGE NUMBER OF CONTRIBUTIONS TO PSYCHOLOGY DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 50 INDIVIDUALS WHO MADE 85 CONTRIBUTIONS.

[15] Sir D'Arcy Power and C. J. S. Thompson, "Chronologia Medica: A Handlist of Persons, Periods and Events in the History of Medicine." New York: Paul B. Hoeber, Inc., 1923. Pp. iv + 278. (See pp. 237 *ff.*)

[16] J. C. Flugel, "A Hundred Years of Psychology." New York: The Macmillan Company, 1933. Pp. 384.

[17] F. H. Garrison, *op. cit.*

that have been employed in the present study. Therefore, some of the advances utilized in the construction of Fig. 12 were used previously in the construction of the other graphs that have been presented. Many of the 801 contributions, however, have not been previously employed.

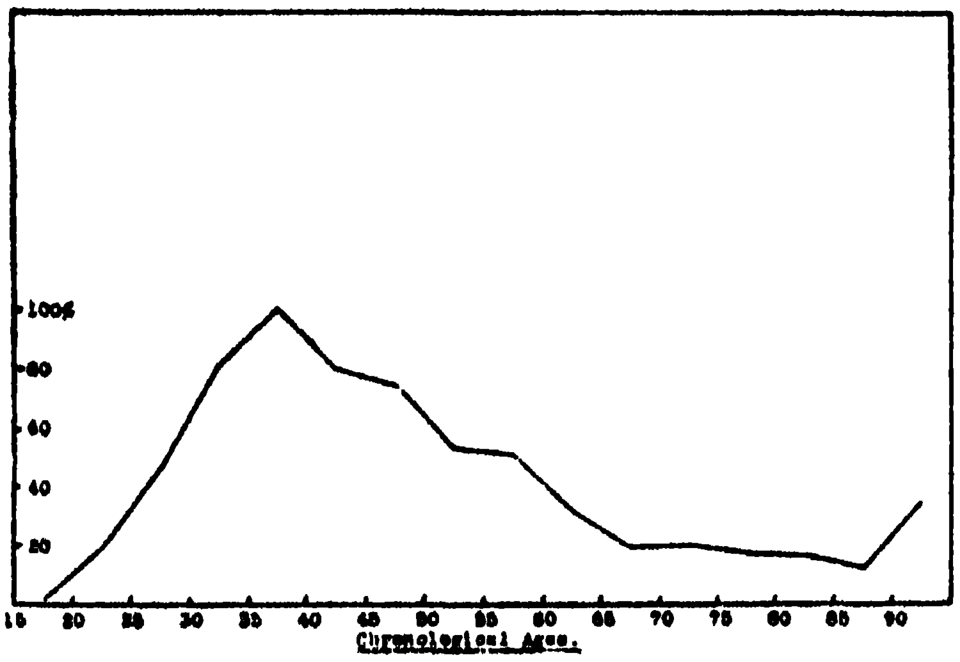

FIG. 12. AVERAGE NUMBER OF ADVANCES IN MEDICINE AND PUBLIC HYGIENE WHICH WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THE CONTRIBUTORS' LIVES. THIS GRAPH PRESENTS DATA FOR 537 INDIVIDUALS WHO MADE 801 CONTRIBUTIONS.

It will be noted that Fig. 12 has a smoother appearance than have most of the age-curves which precede it. This finding is due in part perhaps to the fact that Fig. 12 is based upon a relatively large number of cases. Like ten of the eleven figures which preceded it, Fig. 12 shows a peak at ages 35 to 39, inclusive. On the whole, the assembled data strongly suggest that, in proportion to their numbers, men have made contributions to medicine most frequently while they were still in their thirties. In eleven of the twelve age-curves that are shown herein the peak of productivity occurs at ages 35 to 39, inclusive. In the one remaining curve the peak occurs at ages 30 to 34, inclusive.

FURTHER REMARKS

In the preparation of this article the contributions of great men have been studied. Collectively, these men have probably done more for humanity than have all the warriors and statesmen and politicians who ever lived. It has been a privilege to contemplate the achievements of these creators of modern medicine and surgery. It is a pleasure to know that the age-long search for new means of controlling disease and human suffering is to-day receiving more positive aid and encouragement than perhaps ever before in the history of the race.

In the field of medicine, as in other fields, man's progress has frequently been opposed by ignorance, bigotry, stupidity, ridicule, intolerance and the pressure of poverty. Religious beliefs too have often been a major obstacle to further immediate advance. Some potential contributors to medicine have perhaps been crushed by one or more of these hostile forces; others possibly have only been stimulated by them to fight more vigorously for their convictions. William Harvey reported on the circulation of the blood when he was past fifty, but there is evidence that he discovered this phenomenon some years earlier and delayed publication as a matter of precaution. Histories of medicine reveal that such delay in making announcements of new medical discoveries has been frequent. There often were very good reasons for withholding such announcements. For example, when Harvey finally published his discovery that the blood circulates in the human body his professional colleagues only jeered him and there was an immediate falling off in Harvey's medical practice. Many of his patients refused to be treated any longer by one who gave such clear evidence of what seemed to be obvious insanity.[18]

Because of the time-lag that must often have occurred between the date of a discovery and the date of its publication, it seems evident that, at the upper-age levels, the accompanying age-curves are too high rather than too low. As for the general shape of the curves, and particularly the age intervals at which the peaks are found, it is the belief of the present writer that these are as accurate a picture

[18] *Ibid.*, p. 249.

of the relative productivity of the various age groups as can be obtained with the data that are at present available.

In the first paragraph of this article a warning was uttered about the erroneous impression that is likely to ensue if one depends too much upon one's impressionistic judgment. History provides some conspicuous instances in which impressionistic judgments have been misleading. That oft-misquoted remark which was made by Sir William Osler in 1905 will doubtless be recalled by many who read this article. Before quoting Osler's statement it will be desirable to review briefly the circumstances under which the statement was made. Dr. Osler had served as professor of clinical medicine at The Johns Hopkins University School of Medicine from 1889 to 1905. At the latter date he was appointed regius professor of medicine at Oxford University. At a banquet which was held in his honor Dr. Osler gave a farewell address. Because so many persons had expressed their dismay over his departure, Dr. Osler, with becoming modesty and in a spirit of levity, assured those persons that his departure was inconsequential. In making this remark Osler, who at that time was 56 years of age, meant to imply that his most important work had already been done. In the farewell address which followed Osler stated in somewhat greater detail his thesis that the effective, vitalizing, moving work of the world is likely to be done by men who are between the ages of 25 and 40. The following quotation is taken from a book by Lambert and Goodwin.[19]

> One of Osler's addresses brought him unmerited notoriety. The occasion was his farewell address at Johns Hopkins. In it he said: "I have two fixed ideas well known to my friends, harmless obsessions with which I sometimes bore them, but which have a direct bearing on this important problem. The first is the comparative uselessness of men over forty years of age. This may seem shocking and yet, read aright, the world's history bears out the statement. Take the sum of human achievement in action, in science, in art, in literature—subtract the work of the men above forty, and while we should miss great treasures, even priceless treasures, we would practically be where we are today. . . . My second fixed idea is the uselessness of men above sixty years of age, and the incalculable benefit it would be in commercial, political, and in professional life if, as a matter of course, men stopped work at this age." He then went on in a semi-humorous vein to refer to a novel of Anthony Trollope's describing a college which men entered at sixty for a year's period of contemplation before their peaceful departure by chloroform. "Whether Anthony Trollope's suggestion of a college and chloroform should be carried out or not," he said, "I have become a little dubious, as my own time is getting so short." Unfortunately, the press during a time of lull in actual news scented a sensation in his remarks and soon head-lines appeared saying that "Dr. Osler Recommends Chloroform for Men of Sixty." This precipitated a wide-spread discussion often heated and even bitter by those of whom many had never read what he had actually said. A new phrase —to oslerize—was added to the language indicating the extinction of men of sixty. Osler recognized that he was the victim of misguided reportorial zeal, that explanations under the circumstances were useless, and let the storm blow itself out.

The comments and the criticisms which were elicited by the distorted form in which Osler's remarks received world-wide attention would make a long bibliography. Curiously enough, fate seems to have decreed that Osler will be remembered longest for a remark which he did *not* make.

In the foregoing quotation Dr. Osler speaks of "the *comparative uselessness* of men over forty years of age" and of "the *uselessness* of men above sixty years of age." (The italics are mine.) Although the age-curves that accompany the present article attain their peaks in the thirties, analysis of the data fails to support the thesis that men cease to make useful contributions at *any* specific chronological age level. On the contrary, these data suggest that it is possible for individuals to think creatively and to make invaluable contributions at prac-

[19] S. W. Lambert and B. M. Goodwin, "Medical Leaders from Hippocrates to Osler," p. 326 *f*. Indianapolis: The Bobbs-Merrill Company, 1929. Pp. 331.

TABLE I
SUMMARY OF FINDINGS WITH REFERENCE TO THE CREATIVE YEARS IN MEDICINE

Data used in	Source of data	No. of contributions	No. of contributors	Ave. contributions per contributor	Median age	Mean age	Standard deviation	Years of maximum productivity
Fig. 1	C. B. Morrey	50	41	1.22	38.80	41.20	12.05	35–39
Fig. 2	J. F. Fulton	59	54	1.09	41.33	43.50	12.30	35–39
Fig. 3	V. S. Robinson	52	40*	1.30	37.33	40.10	11.60	35–39
Fig. 4	E. B. Krumbhaar	216	170	1.27	42.50	44.76	13.10	35–39
Fig. 5	E. R. Long	30	27	1.11	43.00	45.67	14.00	35–39
Fig. 6	F. H. Garrison	89	70	1.27	36.38	38.85	11.70	35–39
Fig. 7	B. J. Stern	188	159	1.18	39.50	41.82	12.15	35–39
Fig. 8	F. H. Garrison	97	73	1.33	42.30	43.89	10.45	35–39
Fig. 9	R. H. Major	147	102	1.44	43.79	46.61	13.80	35–39
Fig. 10	Powér and Thompson..	73	44	1.65	34.70	37.02	11.25	30–34
Fig. 11	J. C. Flugel	85	50	1.70	42.75	44.50	11.30	35–39
Fig. 12	F. H. Garrison	801	537	1.49	41.18	43.17	12.45	35–39

* Data for some living contributors are included in this curve.

tically every chronological age level beyond early youth. De Réaumur, for example, was 69 years old when he carried out his memorable observations upon the digestive juices of his pet kite. And, of the 87 works that are included in his "Selected Readings in the History of Physiology,"[20] Fulton reports that 42 of them were written when their authors were past forty.

To cite such facts without surveying all the pertinent data may be misleading. What is to be found when such a survey is made? In Table I the sixth column sets forth the median chronological ages of the contributors whose works have been employed in constructing the 12 graphs that accompany this article. It will be noted that five of the twelve medians fall between ages 30 and 40, and that seven of them fall beyond age 40. The fact that the mid-point of the twelve medians lies at age 41.25 implies that, although the rate of output was greatest prior to age forty, only about half of the sum total of these brilliant medical contributions were made (or first published) prior to age forty. This situation will be readily understood if it is noted that the age-curves fall much more slowly than they rise. It seems obvious that, in medicine and its allied fields, creative thinking does not cease at age forty or even at age sixty.

[20] J. F. Fulton, *op. cit.*

Let us examine Table II, which sets forth the average number of contributions per five-year interval. Forty-nine of the averages that are shown in Table II are based upon the works of individuals who were less than forty years of age, but 87 of these averages are based upon the contributions of individuals who were past forty years of age at the time of announcing their discoveries. A total of 1,888 medical contributions was utilized in the preparation of Table II.[21] Tabulation of the ages of those who were responsible for these 1,888 medical contributions reveals that 906 of the contributions (48 per cent.) were announced by individuals when they were less than forty years of age, whereas 982 of them (52 per cent.) were either made or first published by individuals who were past forty years of age. These figures again emphasize the fact that a distinction needs to be made between rate of contributing and the sum total of output of very superior contributions.

Table III, which is based upon data taken from Garrison,[22] brings out the individual differences in the chronological ages of the contributors even more

[21] This total was obtained by counting each contribution as many times as it was listed in the various chronologies. Some of the contributions were therefore counted more than once. The difference that would have resulted at any one age level in Table II had such duplication been avoided is probably slight.

[22] F. H. Garrison, *op. cit.*

TABLE II

AVERAGE NUMBER OF CONTRIBUTIONS PER FIVE-YEAR INTERVAL*

	Chronological age interval															
	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	
Fig. 1	.005	.101	.030	.040	*.050*	.025	.035	.011	.022	.023	.006					
Fig. 2		.007	.019	.034	*.050*	.031	.016	.029	.028	.000	.026	.001				
Fig. 3†		.010	.030	.060	*.065*	.030	.021	.006	.029	.009	.021	.002				
Fig. 4		.006	.024	.031	*.055*	.033	.026	.019	.034	.021	.014	.007	.011	.014		
Fig. 5			.022	.038	*.046*	.015	.032	.024	.008	.026	.000	.029	.018			
Fig. 6	.003	.022	.031	.044	*.053*	.036	.034	.005	.028	.009	.000	.009	.011			
Fig. 7		.009	.027	.036	*.054*	.033	.036	.011	.015	.014	.012	.000	.014	.000	.022	
Fig. 8		.003	.016	.044	*.052*	.041	.037	.032	.032	.008	.010	.000	.000	.017	.056	
Fig. 9		.009	.016	.033	*.053*	.038	.034	.032	.033	.017	.023	.012	.041			
Fig. 10		.046	.054	*.074*	.047	.034	.040	.031	.006	.000	.024					
Fig. 11			.028	.032	*.080*	.056	.058	.030	.024	.032	.013	.000	.020			
Fig. 12	.001	.011	.026	.045	*.056*	.045	.042	.030	.029	.018	.011	.011	.009	.009	.007	.019

* The peak of each statistical distribution is italicized.
† This figure includes data for some living contributors.

clearly. Thus, Table III reveals that 18 per cent. of the 801 contributions listed by Garrison were either made or first announced by persons of ages 35 to 39, inclusive, that 4 per cent. of them were first published by persons of ages 60 to 64, inclusive, that 10 per cent. of them were first published subsequent to age 60, and so forth.

Letters that have been received from persons who read the first of this series of articles[23] afford convincing evidence that, in spite of all that may be said by way of explanation, the accompanying age-curves will be misleading to some readers. For example, one individual who was permitted to see these age-curves prior to their publication remarked that in his opinion these curves rise and fall "much too rapidly." Further conversation revealed that this individual was laboring under the misapprehnsion that these age-curves are intended to picture the growth and the decline of *individual ability* to do creative thinking.

The present study does not pretend to measure any hypothetical "ability" to do creative work. This study deals only with behavior—the specific kinds of behavior that have been cited. If behavior were due solely to "ability," the interpretation of the data would be very much simplified. In order to picture *individual* growth and decline in creative *ability* it would be necessary to measure creative ability in the same individuals at successive chronological age levels and over a long period of time. Although the present writer has not assembled such data, nor does he know how this could be done, it seems probable that individual age-curves portraying creative ability, if such curves could be obtained, would reveal a much more gradual rise and a much more gradual decline than do the age-curves which are included in this article.

It may well be that future generations will not take seriously many of the pres-

[23] H. C. Lehman, *op. cit.*

TABLE III

(A) NUMBER OF MISCELLANEOUS ADVANCES IN MEDICINE AND IN PUBLIC HYGIENE WHICH WERE MADE DURING EACH FIVE-YEAR INTERVAL OF THEIR LIVES BY 537 INDIVIDUALS ALL OF WHOM ARE NOW DECEASED, (B) PER CENT. OF THE TOTAL OF 801 CONTRIBUTIONS WHICH WERE MADE DURING EACH FIVE-YEAR INTERVAL, AND (C) PER CENT. THAT WERE MADE SUBSEQUENT TO THE BEGINNING OF EACH FIVE-YEAR INTERVAL. DATA FROM F. H. GARRISON

Age group	No. of cont.	Per cent. of total	Per cent. made subsequent to various ages	
		Per cent.	*Age*	*Per cent.*
15–19	3	0.5	15	100
20–24	29	4	20	99.5
25–29	69	9	25	96
30–34	121	15	30	87
35–39	148	18	35	72
40–44	116	14	40	54
45–49	104	13	45	40
50–54	70	9	50	26.5
55–59	63	8	55	18
60–64	35	4	60	10
65–69	17	2	65	5.5
70–74	13	2	70	3
75–79	7	1	75	2
80–84	4	0.5	80	1
85–89	1	...	85	....
90–94	1	...	90	....
Total	801	100	..	....

ent-day attempts to measure the "intelligence" of adults of widely varying ages. Can intelligence be disentangled from such other factors as: (1) motivation to learn; (2) pressure to utilize fully what has been learned; (3) the plasticity of the nervous system; (4) relatively fixed, unalterable attitudes; (5) level of functioning; (6) physical stamina; (7) environmental opportunity; and the like? Is it possible to motivate the older individual to the same extent that the youth can be motivated, if the oldster has attained many of his life goals, and if the youth has reached few of his goals? Is it valid to assume that in our rapidly changing civilization the older adult has had the same intellectual diet (opportunity to learn) as has the younger adult? The present writer knows of no evidence which permits an affirmative answer to the foregoing queries. Nor does the present writer believe that it has been possible for psychologists to apply the law of the single variable when making their studies of "adult intelligence."

The fact that the age-curves apply only to group behavior is not the sole reason why they fall so rapidly. It seems that a second factor which causes the rapid early decrement is the very superior quality of the performance. In previous articles[24] data were published which suggest that the shape of an age-curve varies both with the type of function that is measured and also with the excellence of the performance. Thus, very superior books are likely to be written during a somewhat narrower age range than are books of lesser merit. The foregoing situation seems to hold also for a number of other behaviors—for musical composition, for athletic performance and for several kinds of scientific endeavor.[25] For the above types of behavior, the more noteworthy the performance, the more rapidly does the resultant age-curve descend after attaining its peak. It therefore seems safe to conclude that quality of performance is one reason why the accompanying age-curves fall so rapidly.

Just why brilliant attainment in these diverse fields of endeavor should cease at earlier age levels than does more mediocre performance the present writer does not know. It is easy to speculate with reference to the cause-and-effect relationship; it is much more difficult to validate one's speculations. The rapid descent of the age-curves that are presented herein might conceivably be due either to: (1) the inevitable organic changes that take place within the individual (the reverse of maturation), (2) environmental factors or (3) a combination of organic and environmental factors. It is also quite possible that no general rule is applicable, *i.e.*, some individuals may exhibit an early decrement in the quality of their performance because of organic changes; others may exhibit a similar decrement because of environmental factors or because of a particular combination of organic and environmental factors. If the early decrement in brilliant performance is due to biological factors, it may not be possible to do anything to preclude or even to reduce in amount this early decline. If, however, environmental factors are responsible for the early descent of the age-curves, then it is quite conceivable that the causative factors may some day be subject to a measure of control.

In a study such as this one it obviously would be very difficult and time-consuming to identify the causative (concomitant) factors; in such complex behavior the relationship between cause and effect is likely to be obscure. However, the problem is not hopelessly difficult. Because the promotion of creative thinking is so tremendously important to human welfare, the causative factors should be ascertained if it is at all possible to do so. Certainly, this problem is one that merits serious study.

[24] *Ibid.*

[25] Data which support the above statement with reference to scientific endeavor are not yet ready for publication.

HEREDITY AND MENTAL TRAITS

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It seems to be easier for us to accept as true something we can see, like a meteorite or a club foot, than something we can infer only from indirect data, like the span of years elapsing since the Stone Age, or differences in the educability of human beings. Yet we should not forget in this connection the story in which our professor of logic used to delight, about the fisherman who came home with a large black bass and a tall fish story, "with the fish to prove it!"

When it comes to the problem to be discussed in the present paper, there is an important obstacle to clear thinking which often hampers even the sophisticates who can accept without resistance such unseen truths as relativity mechanics. Not only some observers and interpreters of science, but some research workers themselves, have shown a liability to emotional blocking on questions which concern the mental endowment and plasticity of man. Supposedly this is because the results of studies in this field impinge upon one's life philosophy and attitudes toward his fellows, and thus one comes to care very deeply about the outcomes.

The difficulties and controversies which ensue are understandable, but they mean that the person who would consider the many sources of evidence objectively must use more than ordinary caution. If he is willing to consider only the evidence—apart from the conflicting claims that are frequently made—he will find a surprising amount of consistency in the facts now at his disposal.

We may start with a discussion of intelligence, since this is the aspect of mental life on which the most definitive research has been conducted up to now. Like so many questions having lively interest to-day, the inheritance of intelligence was also considered by the Greeks, and in Plato's "Republic" one may find modern ideas couched in classical allegorical form regarding the biological basis of talent:

> Although your children will generally resemble their parents, yet sometimes a golden parent will produce a silver child, and a silver parent a golden child, and so on, each producing any. . . . There is an oracle that declares that the city shall then perish if it is guarded by iron or copper.

Family Resemblance Studies

It was not until Francis Galton, with his "Hereditary Genius" published in 1869, introduced a method for appraising kin resemblance through the number of highly superior persons who clustered in family lines, that "nature-nurture" investigations began to come from men of science, although the great religions and political states had been built around the idea of men endowed to lead. Galton's study, which showed that men of genius were many times more likely to have genuises among their close relatives than were men at random, stimulated a legion of followers who compiled studies on the defective end (*e.g.*, the Jukes and Kallikaks) as well as the upper end of ability. As quantitative trait-rating devices, and more recently, standardized intelligence tests have come into use, correlation coefficients have replaced mere counts of the incidence of high and low ability in relatives of specified degree. The close comparability of correlations between parents and offspring, or between brothers and sisters, on mental traits and on physical traits such as stature, caused the great biometrician Karl Pear-

son to conclude that "mental characters are inherited in precisely the same way as the physical." It has been often enough pointed out since Pearson's heyday, however, that environment might simulate heredity in producing family resemblance and that additional data are required to disentangle nature and nurture when the biological quality of families is correlated with the environment selected by and even created by the families.

Studies of Twins

The study of twins appeared to many investigators to be a way out of the impasse encountered in ordinary family resemblance studies. As is now widely known by laymen and biologists alike, there are two kinds of twins, one kind derived from a single fertilized ovum, and thus "identical" in heredity, and the other kind derived from two fertilized ova, and thus like ordinary brothers and sisters in degree of hereditary "overlapping." If one-egg twins resemble one another distinctly more than two-egg twins do on physical and mental traits, this is taken as presumptive evidence that heredity is at work. Many studies of twins are now available, and these have dealt not only with intelligence, but with school attainment, physique, susceptibility to disease, interests, attitudes and personality adjustments. We do not wish to encroach upon the field discussed by Rife in his paper on twins in this series of articles, but will take space to comment on a few points relevant to our immediate problem.

In the first place one-egg twins really have a somewhat more similar environment than do two-egg twins, even if reared in their own homes by their own parents. It is shown clearly, for example, in a California study by Wilson, that "identical" twins are treated more similarly by their relatives and friends, and are more similar in habits of eating, sleeping and recreation. While such factors would presumably not affect traits like eye color and finger-print patterns and other physical traits which, because of their stability in the individual, are actually used as criteria for judging whether twins are of one-egg or two-egg origin, they might account at least in part for the greater similarity of one-egg twins in mental development.

There is another approach to the study of twins, on the other hand, which partakes more of the nature of experiment, or at least utilizes the results of social experiments already made. This is the study of one-egg twins who have been separated in infancy and brought up in different environments. To the extent that twin-pair resemblance shows up even when environment has had no chance to contribute to it, we can say that heredity is demonstrated. But when the separated twin-pairs show differences, and particularly when these correspond to identifiable differences in childhood environment, we have a way of appraising non-hereditary contributions. Newman and his colleagues at the University of Chicago have studied twenty separated pairs, and other investigators, including the writer, have studied several additional pairs. The intra-pair mental development of the twins tended to be very similar when differences in their educational opportunities were not too large. This carries the implication that mental differences found among people living in similar communities and having fairly similar schooling are largely *native* differences. There were several pairs of twins, however, whose schooling was extremely dissimilar, and these twins scored far apart on intelligence tests. For example, one young woman had had a college education and had taught school, while her twin had had only two years of grade school education. The difference in their IQ's was 24 points in favor of the college twin, and the differences in their social abilities were fully as striking.

Studies of Foster Children

Probably studies of identical twins reared apart are the most effective of any that have or could be undertaken for unravelling the nature-nurture problem. Such pairs have been located so rarely, however, that other kinds of crucial data have necessarily been sought. Children placed in foster homes during infancy, even when they are not twins, have provided some important evidence, since they have the virtue for research purposes of living in environments that are usually quite different from what their own parents could have provided. We may briefly summarize the chief findings of the main studies of this type:

Theis's 1924 study was the first large follow-up ever made. She found that children placed in foster homes when under five turned out to be more capable adults (on the average) than those placed when over five. It is possible, however, that children who become dependent at later ages come from less promising family stock than those who become dependent in infancy. (Later foster child studies would support this possibility.)

The most interesting finding was a relationship close to zero between home ratings on cultural and material status with "capability" of the foster children as adults, but accompanied by a distinct positive relationship between "kind of care" received and "capability," from which the inference followed: "Undoubtedly the child's adjustment to his foster family governs to a significant degree his adjustment to society, and his adjustment to his foster family has less to do with their standards of comfort and their place in the community than with their human qualities and their understanding." Still further comparisons showed a positive relationship between "capability" and *true* family background. As Folks points out in the introduction, however: "We can not disentangle the factor of inheritance from that of early life with the children's parents and the environment provided by them."

Burks (1928) compared the mental resemblance between 200 foster children (placed when under a year of age) and their foster parents with that between 100 "own" children and "own" parents of similar socio-economic and intellectual range. The resemblance in the foster families was very slight as compared with that in the "own" families. "Own" children averaged 8 points higher than foster children. From results on a composite rating of home environment, it was concluded that measurable factors of home environment (under fairly homogeneous community and educational conditions) contributed about 17 per cent. to the variance of children's IQ's. Wright (1931) later reworked the data and concluded that the total role of environmental (non-genetic) influences in this group could be placed with fair probability between 10 and 50 per cent.

Freeman, Holzinger and Mitchell (1928) tested foster children and foster parents, foster siblings (*i.e.,* foster brothers and sisters), and true siblings growing up in separate homes. The correlation of foster parents and children was somewhat higher than that found in the previous study, but "selective placement" was not ruled out by the method used for acquiring cases. Foster sibling groups showed IQ correlations of .34 to .40, which may have been due partly to environment and partly to selective placement. True siblings of white race in separate homes correlated .44 after allowance was made for poor test standardization in certain age ranges. This value, in turn, may have been due partly to heredity and partly to selective placement. Children who were old enough to test before placement gained about 7 points on the average after several years of residence in good foster homes.

Leahy (1935) undertook an investigation for the purpose of resolving the disparities between the two preceding studies, and went to unusual pains to obtain a group of foster subjects placed when very young and unselectively. Her correlation figures check closely with those of Burks.

The results of the Leahy and Burks studies were recently re-examined by Burks (1938) in cooperation with Sewall Wright in order to evaluate the contributions of nature and nurture to average group differences in intelligence. This problem is essentially different (though not wholly unrelated) from that of ascertaining the factors contributing to the distribution of individual scores. Although hierarchial differences are ordinarily small as compared to individual differences *within* "census groups" of occupations or other variables, they are by no means negligible (*e.g.*, IQ's often average as high as 115 or 120 for children of professional parents, and appreciably below 100 for children of unskilled laborers).

Taking the parental occupational hierarchy found in the IQ's of foster and control children of the two studies, it was possible to estimate through Wright's path coefficient method that the differences in occupational group averages of the "own" children could be attributed about $\frac{1}{4}$ to $\frac{1}{3}$ to environment, $\frac{2}{3}$ to $\frac{3}{4}$ to heredity.

Skodak (1939) recently published a study on foster children of preschool age (continuing studies undertaken by Skeels at the University of Iowa). Widely heralded conclusions arose from average IQ's of 116 reported for 2-year-old foster children in this group, the experimenters remaining seemingly unaware of the faulty standardization and inflated norms of the Kuhlmann-Binet test in the early years. When the data are reworked it is found that year by year (age $1\frac{1}{2}$ to 6) the IQ's average about 6 or 7 points above corrected norms—results which were also found in the previous foster child studies (for subjects of comparable selection), and which can probably be attributed to good environment, although they are not nearly so sensational as the Iowa claims. As in the Freeman study, a group of children old enough to test before placement gained (5.7 after one year and 9.8 points after two years) following foster home residence.

Much was made in the study of the failure of "true family background" to give a prediction of the IQ's of the youngest (two-year-old) children of the group, but no emphasis was given to the fact that foster home status likewise failed to correlate with the IQ's of the children in the youngest ranges. Despite the fact that IQ correlations increased with age both for true parent and foster parent variables, and by the age of six gave a higher value with education of true parents (with whom the children had never lived) than with education of foster parents, the author offered in her main conclusions these *non-sequiturs:* "Placing the child in a good foster home at the youngest possible age makes for development equal to own children in similar homes"; "the relationship between true-family background and the child's mental development is approximately zero"; "the use of true-family histories as a basis for the placement of the child has little or no justification."

Lawrence's 1931 study of children separated from their homes in infancy and tested after some years of institutional life showed an IQ hierarchy following the occupational status of the true father, although the differences were less marked (about 6 points from highest to lowest occupational groups) than with children reared in their own homes. It is not known to what extent the institutional environment, and to what extent atypical representation from the various

occupational groups of children becoming institutional wards, accounts for the reduction in hierarchical differences. To the extent that differences did remain, heredity was probably responsible.

Studies of Changes Under Particular Environmental Influences

In addition to the studies which have attempted to separate the contributions of nature and nurture to individual differences, or to differences between groups of children (or adults), there are a number of studies which approach the problem of environment through the observation of *changes* in mental status under specified conditions.

Improvement in IQ (averaging 5 to 10 points) of foster children placed in good foster homes from poor "own" homes was mentioned in several of the studies just summarized. There are other studies which consider the problem by making *age* comparisons of children growing up under deprived environmental conditions. One of the first of these was Gordon's investigation (1923) of English canal boat children. With almost a total lack of schooling, and with little intellectual stimulation in their houseboat homes, the IQ's of these children showed steady decrease from year to year, so that the average of the twelve-year-olds was nearly 30 points less than that of the six-year-olds. In this study the meagerness of the environment was extreme; other studies have not found as large a disparity between the older and younger subjects of deprived groups, although it has not been unusual to find decreases of 10 to 20 IQ points in a comparable age range among children living in isolated mountain regions, in mill towns of sub-standard cultural opportunities, etc.

Several studies have been undertaken, particularly at the University of Iowa, for appraising the contribution of nursery school training, and of "progressive school" training, to mental development. It is clear that such studies, unless carried out under rigorous experimental control, offer loopholes for great ambiguity, due to the fact that parents who send their children to nursery schools and to private or university-sponsored progressive schools are not a random selection of parents, nor are their children a random cross section of children. Although large claims have been made for the effect of certain types of schooling upon the IQ, it is usually far from certain that the effects are really those of education. Even when groups of young children are "matched" for IQ at the beginning of their nursery school careers, and are later (at college age) found to have disparities that correspond to differences in their educational experiences, the evidence is not clear-cut because IQ's obtained during the preschool years do not give a dependable prediction of developmental potentiality. Thus the later disparities may be due wholly or in part to "selection" of children with higher or lower potentialities. In general it can be said that the better the experimental control in such investigations, the less is the apparent effect of educational variables.

Racial Differences

Though differences in the *average* mental test scores of persons of various natio-racial origins are quite regularly found, these are accompanied by so many differences in environmental training and opportunities, and the *overlapping* among the groups is so large, that anthropologists have quite rightly pointed out the hazards of drawing conclusions regarding innate racial differences merely from mental test surveys. In the United States certain so-called "census groups," in particular the Negroes and some South European groups, especially Italians, have showed a handicapping in mental tests as compared with

North European and Jewish groups. We have very little data, however, by which to interpret the sources of the differences, although there are certain facts that are not incompatible with an explanation on partly biological grounds. We have, for example, a series of studies on the distribution of a variety of simple genetic traits, not associated with racial differentiae *per se,* in natio-ethnic groups occupying different geographical regions. In all such studies (which have dealt with the blood groups, with "taste-blindness" for certain chemicals, with the presence or absence of hair over the middle segment of the fingers, etc.) it has been demonstrated that the incidence rate of traits whose effects are little modified by environment does tend to vary in groups characterized by different racial ancestry. If this is so with genes for physique, then why not with genes for intellect as well?

Such an argument is of course suggestive and not at all conclusive. Of crucial evidence for innate racial differences in intellect we have virtually none. On the contrary, we have a series of studies by Klineberg and his associates who took as subjects ten-year-old Negro children who had lived for varying periods of time in New York City. Recent migrants from the South averaged lowest, and those who were born in New York or had lived there over five years, averaged highest. For example, in one of the studies the former averaged 81 IQ and the latter, 87 IQ. The difference is referred to the better school advantages available to Negroes in the North, although even so, an unexplained disparity remains between the Negroes and Whites. Whether that is due mainly to nature or to nurture is a speculative question that can not be answered by data now available.

Non-Intellectual Mental Traits

We have seen considerable evidence that heredity lays down the limits within which intelligence can develop, but that environmental effects of 5 to 10 IQ points occur under certain conditions, and that effects of 20 points or even more occur under extreme conditions.

Can any similar conclusions be drawn for traits or behavior representing the emotional and volitional aspects of mental life? For interests, for traits of leadership, for anti-social tendencies, for self-control or for proneness to mental breakdown?

Research in these domains seems to have advanced little beyond the place that research on intelligence had reached two decades ago. There are studies of marked personality deviations in kinships, including twins. Such studies show in leadership, nomadism, criminality, psychosis, epilepsy, etc., much the same tendency for clustering in family lines that is found for feeble-mindedness and high ability, and also higher resemblance among one-egg twins than among two-egg twins. But the clinching evidence from foster children and from twins reared apart is available so far in only meager quantity. This is partly because *extreme* deviations like criminality and psychosis happen too rarely to have occurred with much freqnency in the groups of foster children and separated twins that have been studied up to now. Though it might seem that less extreme characteristics of personality could be studied with profit, we have few measuring instruments at all comparable in validity with intelligence tests in the field of personality, and consequently most of the personality data on foster children and twins reared apart—aside from diagnoses of actual pathology, and some scores on rather unreliable tests, are stated in unsystematized terms that are difficult to evaluate. Nevertheless, some of the data, especially on the separated twins, have extreme interest.

Rosanoff has reported on a pair of twin girls separated in infancy and unaware of one another's existence who both developed epilepsy and promiscuous sex behavior. They were recognized as identical twins in the state institution to which they were both committed through their nearly identical appearance and behavior.

Burks has studied a pair of twin girls separated nearly at birth who developed very similar behavior problems in childhood, *e.g.*, nail-biting, enuresis, hyper-irritability. One twin, however, received a more indulgent upbringing, and was "favored child" above a foster sibling reared in the same home, while the other twin was reared under more exacting and less affectionate home conditions. The more favored twin has been happier and more successful in school, social and occupational adjustments.

The Newman, Freeman and Holzinger studies of twins reared apart, as well as containing considerable data on parallel traits of personality, include some striking observations on personality differences that were related to differences in childhood experiences. There was, for example, the boys of a pair reared in the city and country respectively, the city twin impressing the research staff as being "more dignified, more reserved, more self-contained, more unafraid, more experienced, and less friendly." In another pair of boys, the patterns of their foster families, in one case respect and in the other case disrespect for the law, were taken over in a way that markedly affected the trends of their lives.

It is clear that one of the most urgent needs in the field is for more studies on separated twins and foster children making use of the best methods now available for appraising hereditary background and environment as well as personality development. Such studies promise high rewards not only for science, but for man himself in his efforts to come to terms with the requirements of his social *milieu.*

MYSTERIES OF THE MIND[1]

One of the very provocative writers on psychoanalysis is the distinguished Swiss physician, Carl G. Jung, the author of the present volume. A charming person, a profound scholar of wide erudition and a true philosopher, he has exerted a great influence on the thinking of many persons.

Starting as a fellow worker with Freud, he broke with him and set up what may be referred to as a schismatic school of thought, characterized especially by its stress upon what Jung terms the "collective unconscious." To Jung there are depths of the unconscious which lie deeper than early and "forgotten" experiences, which represent, so to speak, the inheritance from untold generations and which are common to all within a given culture. "The collective unconscious, so far as we know, is self-identical in all Western men and thus constitutes a psychic foundation, superpersonal in its nature, that is present in every one of us."

The present volume deals, in rather philosophical style, with individuation and the development of the personality. In this process "let consciousness defend its reason and its self-protective ways, and let the chaotic life of the unconscious be given a fair chance to have its own way, as much of it as we can stand."

In developing his theme, Jung discusses "Archetypes of the Collective Unconscious," "Dream Symbols of the Process of Individuation" (a discussion of a series of dreams of one patient concerning whose history or surroundings no data are given!) and "The Idea of Redemption in Alchemy." There is a wealth of references to Sanskrit art, Coptic and medieval monastic writers, the Gnostic philosophers, and so on, all of which display the erudition of the writer and furnish examples of the recurrence of symbols, in varying times and circumstances.

Chapter 6, "The Development of Personality," becomes a bit more concrete. Jung here makes a plea for the development of adult personalities, pointing out that child-rearing can not best be carried out if the personalities of the adult educators are warped! "Our approach to education suffers from a one-sided emphasis upon the child who is to be brought up, and from an equally one-sided lack of emphasis upon the deficient upbringing of the adult educator."

A personality he defines as "a definitely shaped, psychic abundance, capable of resistance, and endowed with energy." This, he warns us, is an adult ideal, not properly to be foisted upon children. Personality, that is, of the adult, is not manifested "without definiteness, fullness and maturity" (p. 285)—such aims do not fit the child. Some parents, in trying to "do their best" for their children, succeed only in overdoing what has been most neglected in themselves!

Later in the same chapter Jung devotes some space to another kind of "personality," that is, the "historical personality," or what Carlyle would refer to as the "hero." Some few persons, Jung says, learn to liberate themselves from convention, from "the collective fears, convictions, laws and methods" of the mass of mankind (p. 290). This ability he attributes to a "vocation: an irrational factor that fatefully forces a man to emancipate himself from the herd and its trodden paths" (p. 291).

The volume is an interesting production of a great thinker, a thinker with a well-stocked mind but with an irresistible urge to speculate. As one finishes

[1] *The Integration of the Personality.* Carl G. Jung, M.D. Translated by Stanley M. Dell. 313 pp. $3.00. 1939. Farrar and Rinehart.

reading it, he is likely to agree with Jung that, "what is called personality is a great and mysterious question. All that can be said about it is curiously unsatisfactory and inadequate, and there is always the threatening danger that the discussion will lose itself in mere talk that is as redundant as it is hollow."

WINFRED OVERHOLSER, M.D.

EARLY AMERICANS[1]

IT has been said that, while urban civilized man may or may not have horse sense, primitive preliterate man must have it. Penobscot Man is a record, by the foremost living field worker among our northeastern American Indians, of the manner in which the Penobscot of the Maine woods used their wits to make their living and to survive and thrive as a group. Oddly enough, with all our three or four centuries of white contact with the northeastern Indians, this is our first modern technical monograph on any one group of these forest hunters. It covers all phases of culture—from food to art to society and the life cycle—except religion and folklore.

The data were gathered by Speck chiefly in 1907–14, living and camping with the older men of the tribe. Later visits in 1914–1918 and 1936 helped to fill out the record.

The attempt is not to reconstruct the prehistoric past of the Penobscot, but to present a picture of them as they were in the historic era when native ways and institutions were midway in transition to European forms under French and, later, English influence. A 12-page postscript gives an impressionistic but illuminating sketch of life to-day among the Penobscot. The old era is gone, but not all; beneath the Europeanized surface still lurks no little of the pride of tongue and ancestry, the flair for the hunt, the lure of the rippling waterways, the longing for the deep forest. It is a very human people whom Speck reveals to us, with their loves and their ambitions and their quiet—and often broad—humor. One thumb-nail sketch, that of old Louis Nicholas, is unforgettable, of surpassing pathos, a symbol of the death of a whole culture.

All in all, Penobscot Man is a notable addition to the long list of splendid papers and monographs Speck has given us. It is thoroughly scientific and thoroughly readable. It is crammed with new significant data. The reviewer has no doubt it will take its place among the permanent classics of American Indian ethnology.

JOHN M. COOPER

[1] *Penobscot Man: The Life History of a Forest Tribe in Maine.* Frank G. Speck. Illustrated. xx + 325 pp. $4.00. 1940. University of Pennsylvania Press.

TOTAL WAR UNDER THE MICROSCOPE[1]

THE most recent addition to the excellent series of Experimental Biology Monographs of the Macmillan Company is a scholarly and original contribution by Valy Menkin on the mechanisms of inflammation. Both the author and the editors of these monographs are deserving of hearty congratulations. The printing and illustrations are worthy of the work. Dr. Menkin briefly and critically reviews earlier theories of the mechanisms and dynamics of inflammation before amplifying his own significant factual and theoretical contributions of the last few years. There is a rare lack of bias in his evaluations of work not in complete accord with his own observations.

The book is highly recommended to those versed in the science of medicine and the related disciplines, but it is rather too technical for the average lay reader.

The author develops an invitingly

[1] *Dynamics of Inflammation. An Inquiry into the Mechanisms of Infectious Processes.* Valy Menkin. Illustrated. xii + 244 pp. $4.50. The Macmillan Company.

logical concept of the dynamics of inflammation in which the role of chemical mediators, such as leukotaxine, is stressed. This theory of pathogenesis of the progressive changes arising in the development of inflammation is, of course, not the final word, but it represents an extremely feasible working hypothesis and should serve to further correlate the facts and ideas concerning cellular reaction to injury. To the suffering individual whose sore finger is the battleground of invading microorganisms, inflammation will mean redness, swelling, heat, pain and tenderness. Dr. Menkin has sought to reveal the intricate machinery, chemical and organic, involved in tissue defense against the invaders: total war under the microscope.

EDWARD J. STIEGLITZ

MODERN SCIENCE FOR THE AMATEUR[1]

A. FREDERICK COLLINS is called by his publishers "the master hobbyist" because he has written hundreds of articles and scores of popular books, most of them addressed to amateurs and intended to make attractive the actual work of construction and operation in such fields as photography, gardening, aviation, magic, microscopy, wireless, motors and stamp collecting. He has done a tremendous service in this encouragement of the amateur and in this emphasis on the experimental point of view. For not only does science begin with such direct experience, but probably any valid culture for the mass public must be based on the use of the hands, on things to do. All else follows.

[1] *Science on Parade.* A. F. Collins. Illustrated. xi + 314 pp. $3.00. November, 1940. D. Appleton-Century Company.

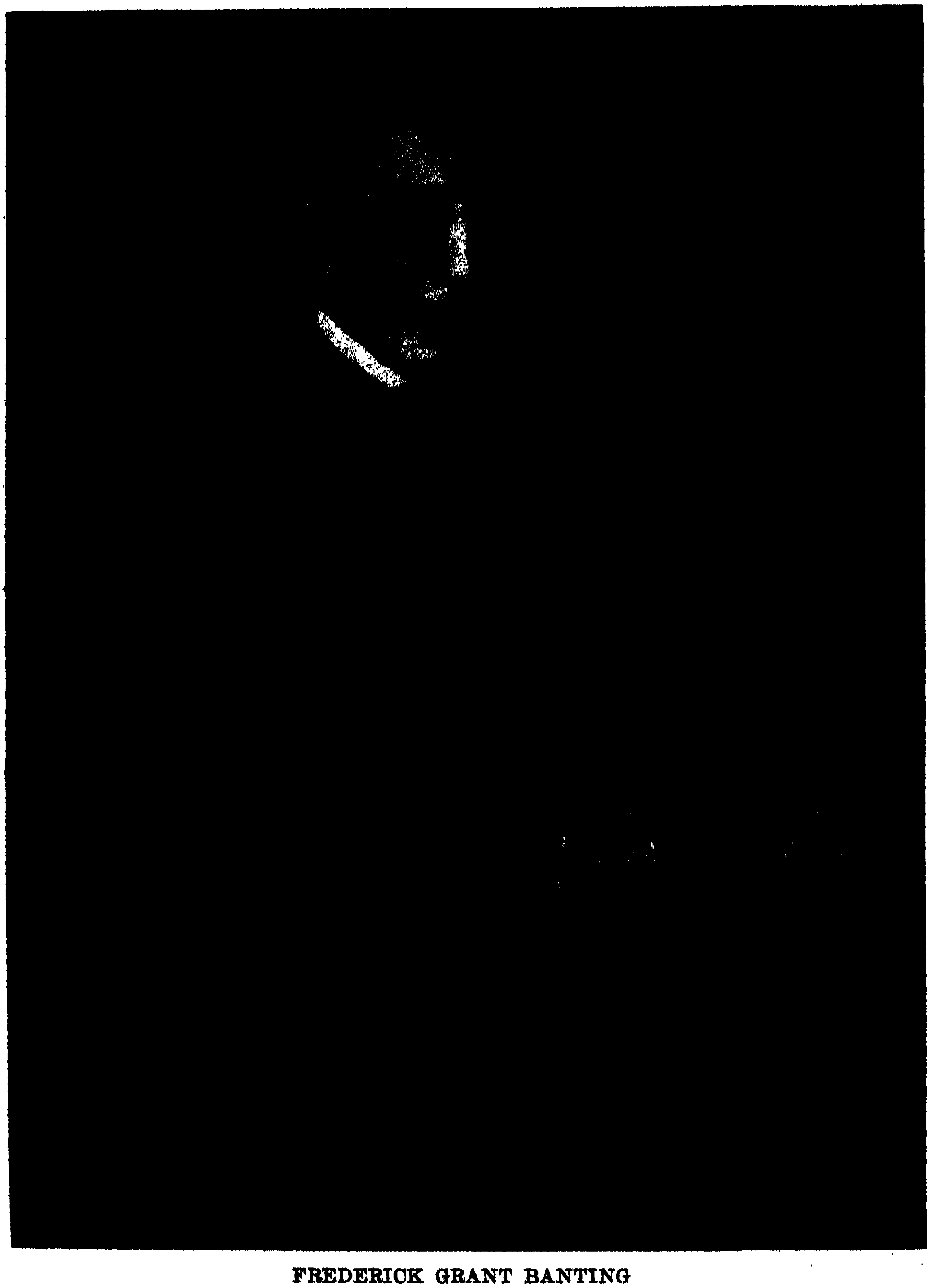
It is therefore interesting to have from him now this book which still maintains primary interest in construction and operation but describes recent advances in industry based on progress in science. These include the Atlantic super-clippers, synthetic materials, artificial lightning, the sterilamp, fluorescent lighting, the electronic piano, color photography, radio facsimile, synthetic speech and television. All these have had ample publicity and are, of course, adequately described in the technical journals, but Mr. Collins's excellent diagrams and clear exposition are the first solid information to amateurs on how they work.

Mr. Collins is at his best in electricity, hence in describing television and facsimile. He is not so specific in the chemical chapters such as synthetic materials and photography, for he assumes less knowledge on the part of his readers. It is, of course, not so easy to be an operating amateur in these chemical matters. Here too he encounters the difficulty of using trade names for the various products and can not be fair to all manufacturers.

Any reviewer must also plead for better titling. The topics discussed do not begin to make a full parade of recent science. Neither can the use of the ultraviolet lamp in sanitation justify the chapter title, "Health on Parade." The fact that the book is otherwise authoritative and precise makes it the more regrettable that the title and chapter headings are vague and grandiose.

This is the kind of book that the amateur needs as an outgrowth of his own more restricted handiwork. It is especially a book that can be recommended for school libraries.

GERALD WENDT



FREDERICK GRANT BANTING

THE PROGRESS OF SCIENCE

FREDERICK GRANT BANTING, DISCOVERER OF INSULIN

ON February 21st there perished in the wilds of Eastern Newfoundland, as the result of injuries sustained in the crash of a plane England bound, Major Sir Frederick Grant Banting. Thus there came to a tragic end the romantic life of a lovable character and a truly great man. I was perhaps the last of his close friends to see him alive, as we had spent several happy hours together just prior to his departure on his important war-time mission.

Banting was born in Alliston, Ontario, Canada, November 14, 1891, the son of William Thompson Banting and Margaret (Grant) Banting. He was educated at the Alliston public and high schools and at the University of Toronto. He joined the Canadian Army Medical Corps as a private in 1915, and served in Canada, England and France from 1915 to 1919. He was wounded at Cambrai in 1918 and was awarded the Military Cross. After the war he was resident surgeon in the Sick Children's Hospital of Toronto for one year. He practiced medicine in London, Ontario, and held a part-time assistantship in the Department of Physiology in the University of Western Ontario until May, 1921. On May 16 of that year he began work on the problem of the internal secretion of the pancreas in the Department of Physiology of the University of Toronto, under the direction of Professor J. J. R. Macleod. Thereafter, he was lecturer in pharmacology there from 1921 to 1922, senior demonstrator in medicine from 1922 to 1923, and professor of medical research from 1923 until his death. He was honorary consulting physician to the Toronto General Hospital, the Hospital for Sick Children and the Toronto Western Hospital.

He received a degree of doctor of laws from Queen's University in 1923, and doctorates of science from the University of Toronto in 1923, from Yale University in 1924, McGill University in 1939 and, posthumously, from the University of Montreal last March. He was elected a fellow of the Royal Society in 1935.

In June, 1934, Banting was raised to knighthood as a Knight Commander of the Civil Division of the Order of the British Empire. In 1923 he was awarded the Nobel Prize, and in the same year the Parliament of Canada voted him a life annuity.

Banting was a most unselfish individual. He was always mindful of helping others and it was almost a religion with him to encourage, stimulate and assist young research workers. He did not believe that young students should lightly take up research work, but only when they had an impelling urge to do so. Banting's philosophy in regard to this was perhaps never expressed better by him than in the closing paragraphs of his Cameron Prize Lecture to the students of Edinburgh University in 1928.

> The question may arise in the mind of someone present—What may I do? Do not enter upon research unless you can not help it. Ask yourself the "why" of every statement that is made and think out your own answer. If through your thoughtful work you get a worthwhile idea, it will get you. The force of the conviction will compel you to forsake all and seek the relief of your mind in research work. You can prepare yourself for work. The paintings of the great masters, the compositions of great musicians, the sermons of great preachers, the policies of great statesmen, and the campaigns of great generals, do not spring full bloom from barren rock. Your training here is but a preliminary step in preparation for your life work. Mackenzie practiced thirty years before he wrote his book on the heart. Training is required. As Osler says, "live in a day-tight compartment doing each day's work well." If

you are a true student you will be more dissatisfied with yourself when you graduate than you are now. It is not within the power of the properly constructed human mind to be satisfied. Progress would cease if this were the case. The greatest joy in life is to accomplish. It is the getting, not the having. It is the giving, not the keeping.

I am a firm believer in the theory that you can do or be anything that you wish in this world, within reason, if you are prepared to make the sacrifices, think and work hard enough and long enough.

Banting and the writer first met in the early spring of 1921 in the office of Professor J. J. R. Macleod in the Department of Physiology of the University of Toronto, under whom we had both come to work. That day there began a close association between us, and although this was for a time strained by certain misunderstandings, it grew closer with the passing years. I recall quite vividly how impressed I was with Banting and his problem, which was nothing less than a frontal attack on the pancreas to obtain its elusive internal secretion. My own problem, the effect of pH upon the blood sugar, seemed insignificant by comparison, but I had come to work with a man, whereas Banting had a problem which even at that time superseded such things as personalities and graduate training. I feel that I was very fortunate to have been a worker in Macleod's laboratory at the time that Banting started his first investigations and to have known of the progress of this work at first hand. He was most anxious that I should become a co-worker with him. I assured him that I would be delighted to do this, but that I would have to wait until my revered chief, Professor Macleod, said the word. Some weeks later, at a time when Banting's early experiments, in which he had been assisted by C. H. Best (now Professor Best), had in my opinion established completely the existence of insulin, Dr. Macleod asked me to join in the work. The part which I was able to contribute subsequently to the work of the team was only that which any well-trained biochemist could be expected to contribute, and was indeed very trivial by comparison with Banting's contribution.

During the past few years, in connection with the work of the National Research Council of Canada, it has been again my privilege, together with others, to be associated with Banting. The high regard in which he was held by his colleagues in the Research Council, not only on account of his own personality, but for his genius in organization, insight and leadership, can not be expressed better than in the words of the president of the council, Lieutenant-General McNaughton, now heading the Canadian Corps overseas. In a recent tribute to Banting, General McNaughton said in part:

In all our work he gave his best, painstaking help in the administration of the Council's manifold activities, time freely devoted to other sciences as well as medicine, vision and insight and leadership, loyal cooperation and unfailing help and generous encouragement to those who laboured with him in the field of scientific research, modesty almost to a fault. He will be very greatly missed from his place at our Council table. When the dark shadow of war overtook Canada and The Empire he came overseas with the desire for service again with the forces in the field but at my personal request he gave this up unselfishly to undertake the organization of research of far reaching importance to us and which he alone could do. It is in the prosecution of this work that he has given his life.

It is too early for an adequate assessment of Banting's work to be made, but it is certain that at least three of his major accomplishments will long be remembered. These are—the discovery of insulin, the development of the Department of Medical Research of the University of Toronto, which has done and will continue to do notable work of an investigational character, and the initiation, the organization and the carrying-out of research work relating to the war effort.

J. B. Collip

McGill University

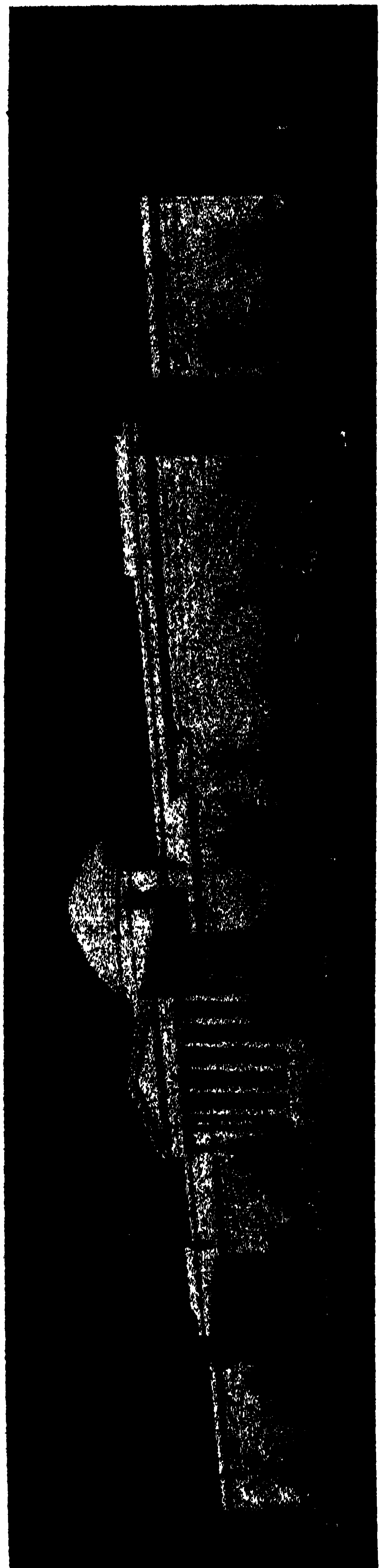
THE NATIONAL GALLERY OF ART[1]

On March 17, President Roosevelt dedicated the new National Gallery of Art at Washington. On the following morning the Gallery, with the Mellon and Kress Collections on view, was opened to the public. The building, under construction for almost four years and recently completed at a cost of fifteen million dollars, was made possible by the gift of the late Andrew W. Mellon. The dedication, on March 17,

[1] The Smithsonian Institution is legally the owner of the National Gallery of Art, including its building and its permanent collections. Title has already passed to it covering the building, and the Mellon and Kress collections. The chancellor of the Board of Regents of the Smithsonian Institution and the secretary of the institution are ex-officio members of the board of nine trustees of the National Gallery. The Smithsonian Institution already owned the Freer Art Gallery, a repository for Oriental Art, and administers the National Collection of Fine Arts and the National Portrait Gallery. Dr. C. G. Abbot, secretary of the Smithsonian Institution, recently expressed the hope that some day a worthy and commodious gallery may be elected for the preservation of the National Collection of Fine Arts, the National Portrait Gallery and the exhibition of contemporary art. Such a gallery will serve not only to receive types of art not within the scope of the National Gallery, but also, as time goes on, to be to some extent its feeder, as contemporary art stands the test of time and itself becomes classic.

"THE ADORATION OF THE SHEPHERDS," BY GIORGIONE

THIS PAINTING, ALSO KNOWN AS THE ALLENDALE ADORATION, IS CONSIDERED TO BE AMONG THE MOST BEAUTIFUL EXAMPLES OF THE ART OF LANDSCAPE DURING THE ITALIAN RENAISSANCE. PART OF THE KRESS COLLECTION, IT IS REPRESENTATIVE OF THE VENETIAN SCHOOL.



THE NEWLY DEDICATED NATIONAL GALLERY OF ART IN WASHINGTON, D. C.

THE BUILDING, CONSTRUCTED OF PINK TENNESSEE MARBLE, LIES IN THE MALL AT A SHORT DISTANCE WEST OF THE UNITED STATES CAPITOL. ITS EXHIBITION AREA AMOUNTS TO ABOUT 238,000 SQUARE FEET. FOUR YEARS WERE REQUIRED FOR ITS CONSTRUCTION.

consummated the plan formulated by Mr. Mellon during the years he spent in Washington as secretary of the treasury, and later announced in a letter to President Roosevelt in December, 1936. In this letter, Mr. Mellon offered to build and to give to the nation an art gallery. He stipulated that the then proposed edifice should not bear his name but should be designated as the "National Gallery of Art." His gift included his collection of paintings and sculpture, which he hoped would become the "nucleus" of a great national collection. The gift was accepted by the Act of Congress of March 24, 1937, and a site for the building extending along Constitution Avenue and the Mall from Fourth to Seventh Streets was provided.

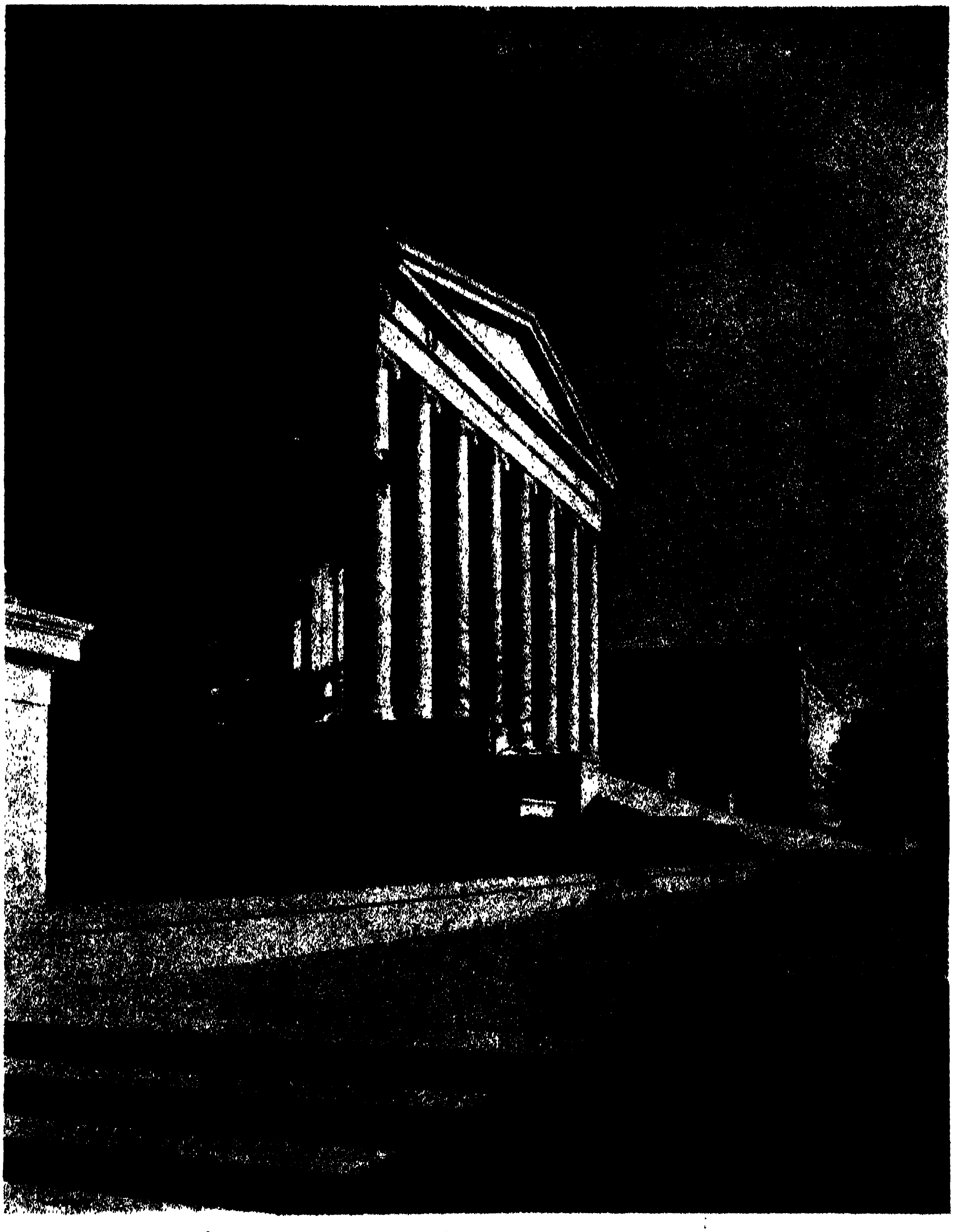
Funds for the maintenance of the gallery, in line with the general practice for the maintenance of other federal museums and art galleries, are to be provided by annual Congressional appropriations.

The architect for the National Gallery of Art was the late John Russell Pope, who died a few weeks after the groundbreaking ceremonies in June, 1937. Pope's associates, Otto B. Eggers and Daniel Paul Higgins, of the firm of Eggers and Higgins of New York City, carried the architectural phase of the construction to its completion.

Conceived as a repository for great masterpieces of art, the gallery is considered by critics to be an outstanding achievement in the field of architectural art.

The pattern of the building consists of two square wings extending from a central rotunda, surrounded by a low dome. Ionic columns supporting broad pediments on the longitudinal faces of the structure, suggest classic Greek influence in architectural design. In general outline the gallery is in harmony with other federal structures along Washington's Constitution Avenue.

In dimensions, the building is 785 feet



THE MAIN ENTRANCE TO THE NATIONAL GALLERY OF ART

THE IONIC COLUMNS SUGGEST CLASSIC GREEK INFLUENCE IN ARCHITECTURAL DESIGN. AMONG THE BUILDINGS VISIBLE FROM THE STEPS ARE THE SMITHSONIAN INSTITUTION, THE U. S. NATIONAL MUSEUM, THE ARMY MEDICAL MUSEUM AND THE U. S. CAPITOL.

long and 305 feet wide. It was erected on a foundation of 6,700 concrete piles. It is constructed principally of hard-surface, rose-white Tennessee marble. Completion of the structure required 800 carloads of this material and represents one of the world's most extensive applications of marble in a single building. The marble in the walls is graduated in color, from strong tones in the lower courses to blend imperceptibly into nearly pure white at the cornice.

The main entrance to the building is through two twelve-ton bronze doors facing Washington's famous Mall. The Mall entrance leads directly to the rotunda, one of the outstanding architectural features of the gallery. The rotunda is one hundred feet in diameter and of equal height. The dome, with its glass-covered oculus, is supported by 24 Ionic columns, carved in Vermont from dark-green Italian marble, quarried in Europe. In the center of the rotunda is a gray marble fountain surmounted by Giovanni Bologna's famous bronze figure of Mercury, from the Mellon Collection, made probably between 1575–1600.

Extending east and west from the rotunda are two large halls or galleries, almost 75 feet wide and more than 100 feet long, which will contain large pieces of sculpture. Already in place in the west hall are two life-size bronze statues of Bacchus and Venus Anadyomene, made about 1525 at Florence by Sansovino. They were once part of Napoleon's National Collection in Paris, acquired by him from northern Italy as "war booty" following his successful campaign against

THE ROTUNDA OF THE NATIONAL GALLERY OF ART

SHOWING A SPECIALLY DESIGNED FOUNTAIN SURMOUNTED BY A BRONZE STATUE OF MERCURY BY GIOVANNI BOLOGNA. THIS STATUE IS ONE OF THE THREE CASTS GENERALLY CONSIDERED TO BE THE ORIGINALS OF THIS FAMOUS REPRESENTATION OF THE MESSENGER OF THE GODS.

Austria. During an uprising in Paris in May, 1871, with the Commune in power, the great Palais Royal was fired by a mob, and the statue of Venus was thrown from a window just in time to prevent its destruction. The scars of this adventure are still visible.

Each of the sculpture halls terminate in a large and beautifully patterend garden court. Seats for the convenience of gallery visitors have been set about the courts in the midst of growing flowers and evergreens. In the center of each court stands one of two well-known fountains which graced the gardens of the palace of Versailles over 250 years ago.

These fountain groups were modeled in lead on the order of Louis XIV between 1670–1675. The fountains are similar in size and general effect and were part of the decorations for the celebrated "Theatre d'Eau" at Versailles. Both are group sculptures; one, by Pierre Legros, represents two winged cherubs playing with a lyre, and the other, by Jean-Baptiste Tubi, depicts two similar figures at play with an irate swan.

The two hundred thousand and more square feet of exhibition area which radiates from the main corridors and garden courts provide space for almost one hundred separate galleries.

The galleries are lighted by natural daylight, diffused through specially treated glass lay-lights. At night or on dark days the paintings and sculpture are illuminated by specially designed floodlights placed above the diffusing glass in the ceilings of the galleries.

"MADONNA AND CHILD,"
BY ROSSELLINO, MARBLE RELIEF OF THE FLORENTINE SCHOOL WAS EXECUTED BETWEEN 1475 AND 1480.

The Mellon Collection covers the principal European schools from about the year 1200 to the early nineteenth century and includes a number of early American masterpieces. The Kress Collection exhibits Italian painting and sculpture and illustrates the complete development of the Italian schools from the early thirteenth century in Florence, Siena and Rome to the last creative moment in Venice at the end of the eighteenth century.

B. W.

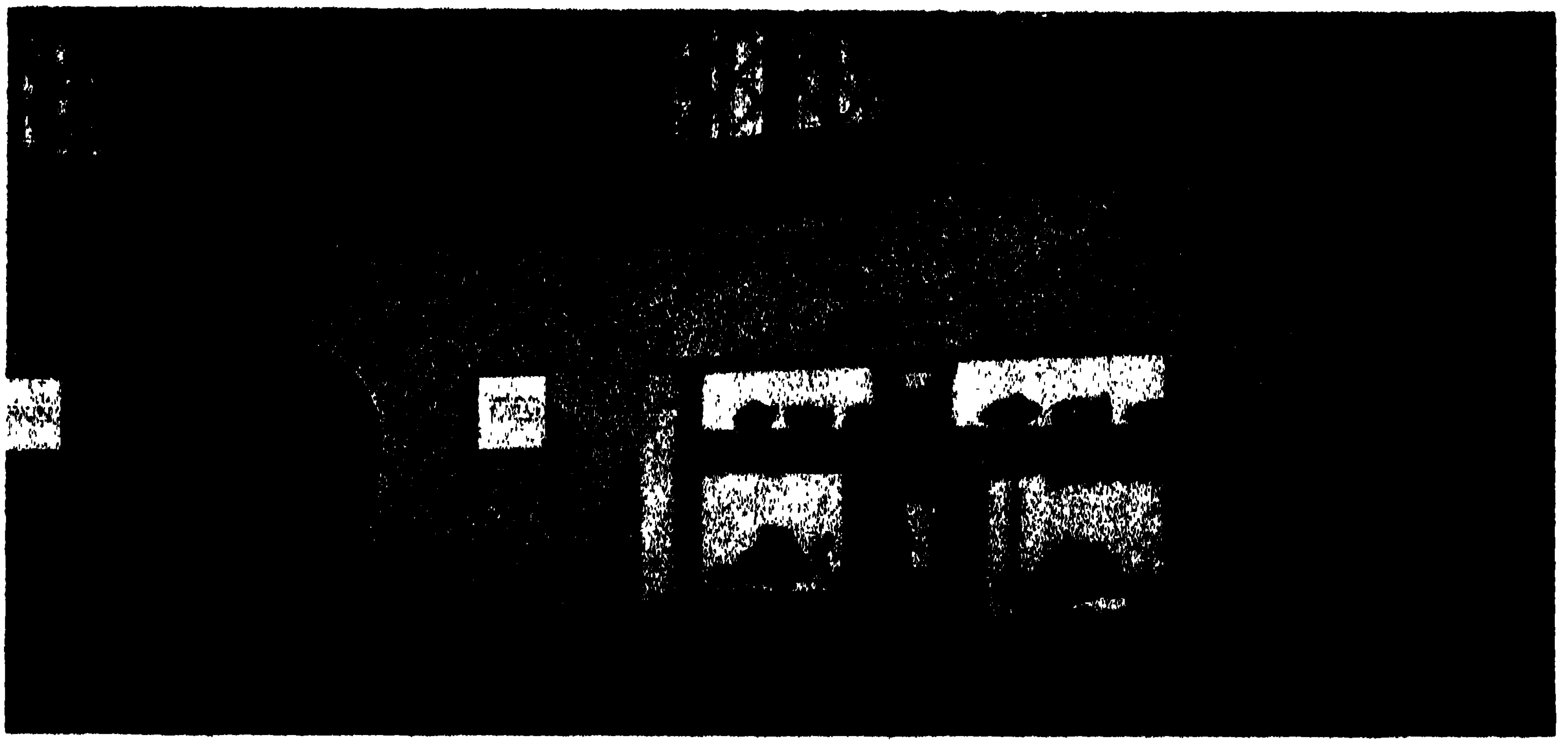
THE GEOLOGY ALCOVE OF THE SMITHSONIAN'S NEW "INDEX EXHIBIT"

GEOLOGY is the study of the earth. Besides the air (atmosphere) and the oceans (hydrosphere), the earth is thought to consist of a layer of light rock 35 miles thick, a layer of heavy rock 1,000 miles thick, a zone of iron and stone 1,000 miles thick and a central iron core nearly 2,000 miles in diameter. The Smithsonian Institution confines its attention, in the field of geology, largely to the scientific problems of the upper layer of 35 miles. This is perhaps due to its ownership of extensive collections of fossils, minerals, rocks and ores, from this restricted thin

skin of our earth. Since, too, it possesses one of the world's few large meteorite collections, it devotes much attention to these rocks from outer space. The geological display of the new "Index" exhibit is designed to illustrate, in a limited way, the research interests of the Smithsonian.

The central motif of the geological exhibit is a large, slowly rotating globe, with the terrestrial continents, deep buff in color, in relief upon a deep blue sea, signifying in a simple manner that the science of geology concerns itself with the features, both external and internal, of our own planet. Two brief labels explain the constitution of the earth and the Smithsonian's scope of interest. On one side of this central motif are selected exhibits of the Smithsonian's work in paleontology, "the study of fossil animals and plants," and on the other, some phases of its interest in mineralogy, "the study of minerals."

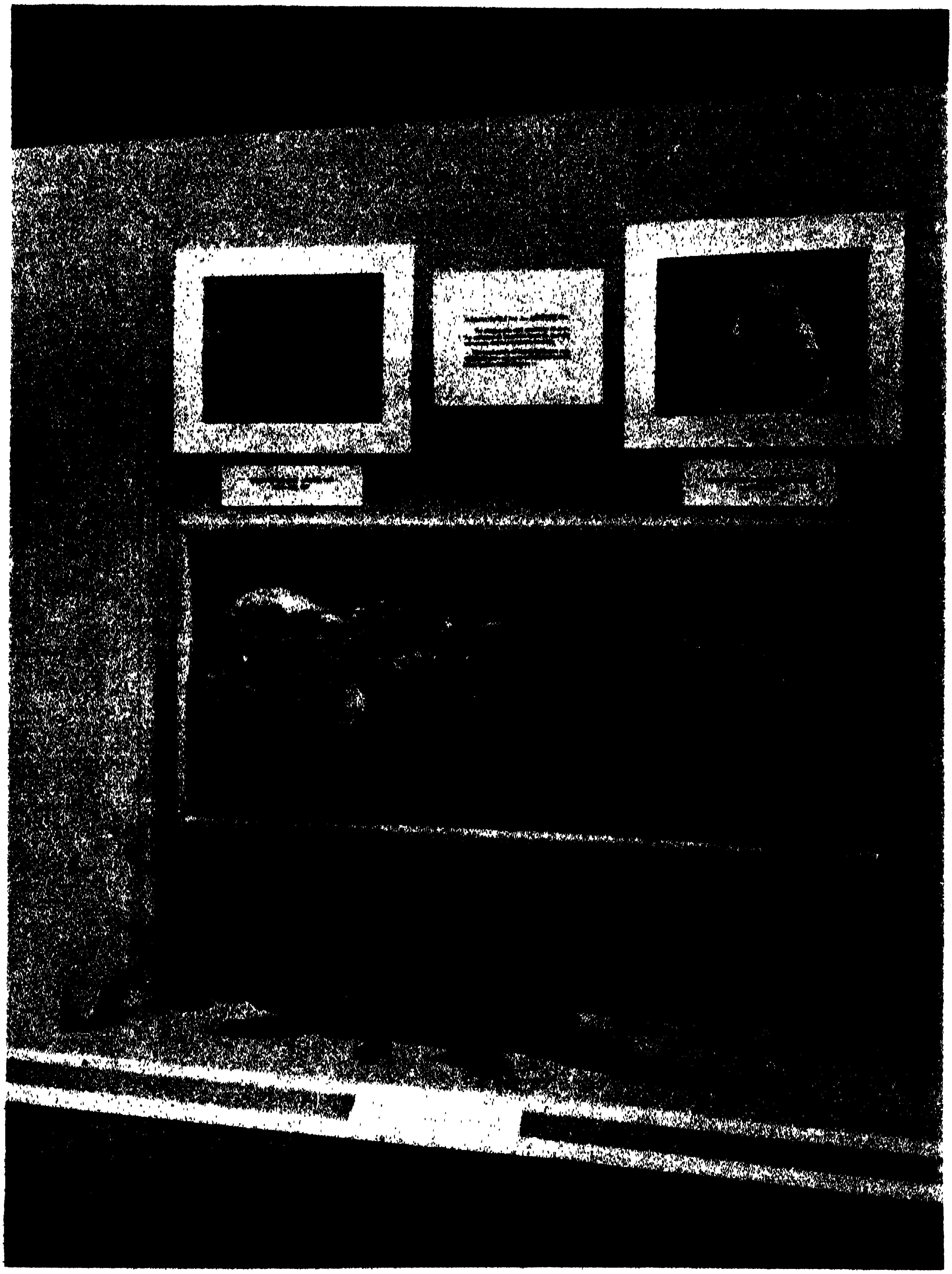
Down the center of the paleontology section is a column of three small dioramas, showing characteristic scenes from three ancient geological eras: for the Cenozoic, a three-toed horse and a primitive carnivore against a background of flowering trees; for the Mesozoic, an armored dinosaur against palms and cycads; and for the Paleozoic, the struggle for existence between trilobites and cephalopods in an ancient sea. One panel shows, as an example, the activities of the vertebrate paleontologists, work both in the field and in the laboratory on an extinct lizard from the Cretaceous epoch, 100,000,000 years ago, one of the most ancient lizards found in North America. This includes a block of rock with two articulated skeletons worked out in relief, and a restoration of the lizard based upon the scientific study of these and other skeletons found associated with them. The other panel illustrates some researches in Permian invertebrate paleontology, with blocks of fossil-bearing limestone, both as found in the field and as partially prepared in the laboratory; and the remains of fossil animals, bryozoans, brachiopods, molluscans and other forms, with their delicate features preserved in silica for 200,000,000 years. Studies on these forms increase our knowledge of the history of life during this remote period.



A PORTION OF THE GEOLOGICAL SECTION OF THE SMITHSONIAN'S EXHIBIT

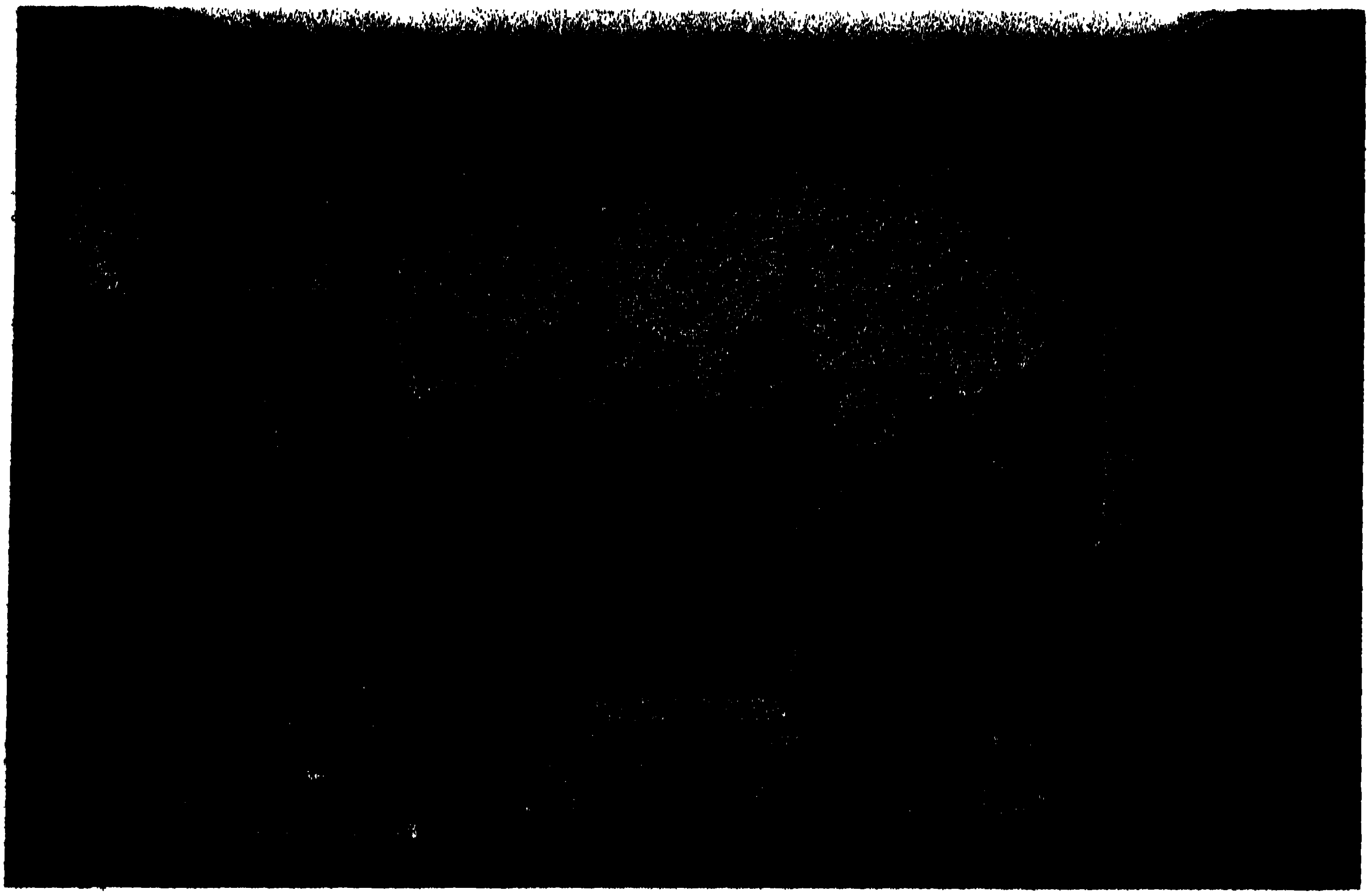
A REVOLVING TERRESTRIAL GLOBE TYPIFIES THE SCIENCE OF GEOLOGY.

On the other side, relating to mineralogy in its broadest sense, is a long panel showing by an illuminated scene a meteorite in flight, and characteristic indi-



THE STUDY OF A FOSSIL LIZARD

PHOTOGRAPHS SHOW A SMITHSONIAN EXPEDITION IN THE FIELD AND LATER WORK IN THE LABORATORY. BELOW THESE ARE A PREPARED SKELETON AND A RESTORATION OF THE LIZARD.



SOME MINERALS FROM THE PRINCE OF WALES ISLAND, ALASKA

AGAINST A PAINTED BACKGROUND OF THE LOCALITY ARE ARRANGED SOME OF THE MATERIALS COLLECTED DURING A SMITHSONIAN EXPEDITION.

viduals of the three main types of these strange visitors from outer space: the stony, stony-iron and iron meteorites. Below is a panel of crystallized minerals from Prince of Wales Island, Alaska; epidote, garnet and others against a painted background of the locality and a small "telescope" in which one can view the work of collecting these minerals on the distant mountain slope. The specimens were selected, not only to show the character of material with which the mineralogist works, but the beauty of the mineral kingdom as well. A second case shows typical silver-lead and silver-gold ores from Mexico and some of the minerals in well-crystallized groups, that are commonly found in these ores. This exhibit illustrates the economic mineralogy of the rich mineral regions of Mexico, in which the Smithsonian has long been interested. Finally, a small recessed case shows a brilliant cut gem of topaz gleaming in a dimly lighted recess and a topaz crystal of the same material, both from the gem mines of Brazil.

Each year the Smithsonian conducts geological explorations and researches in various parts of the world. These exhibits illustrate some of them.

W. F. Foshag
Smithsonian Institution

PALEONTOLOGICAL EXPEDITION INTO THE SOUTH DAKOTA BADLANDS

A collection of more than 175 fossil specimens made last summer in the South Dakota Badlands by a joint paleontological expedition of the National Geographic Society and the South Dakota State School of Mines is undergoing study. Preliminary investigations in the workrooms of the Museum of the School of Mines indicate that many of the fossils are rare and that several represent species and genera new to science. It is believed probable that the two most strik-

A FERTILE HUNTING GROUND

IN SUCH ERODED AREAS OF THE WHITE RIVER BADLANDS, SOUTH DAKOTA, THE EXPEDITION FOUND MORE THAN 175 SPECIMENS OF FOSSIL BONES OF MAMMALS, BIRDS AND REPTILES. THE CAPSTONES ARE OF CHANNEL SANDSTONE OVERLYING SHALES.

CAMP OF THE PALEONTOLOGICAL EXPEDITION IN THE WHITE RIVER BADLANDS

ing specimens found will fall into the latter group: a rhinoceros skull 28 inches long, and the skull of a giant pig which measured, when alive, fully eight feet from snout to tail.

Among other specimens found by the expedition were fossil bones of tapirs, graceful little three-toed horses (the remote ancestors of present-day horses), protoceros (remotely related to deer and antelope), the little-known ancodus and a number of small rodents. Rarest of the specimens are bones of birds—only a few have previously been found in the Badlands. The prize find, which may belong in this group or which may be of reptilian origin, was a fossil egg still firmly held in its matrix of rock. A few plant fossils were found: fossil hackberry seeds and petrified hackberry wood.

Led by Dr. Joseph P. Connolly, president of the School of Mines, and James D. Bump, curator of the museum, the expedition, including seven other members, established camp in a fantastically eroded region 25 miles from the nearest highway. Their work was carried on in the summer sunshine, where mid-afternoon temperatures frequently reached 120 and 130 degrees Fahrenheit. Some of the heaviest specimens were found near the tops of high, slender pinnacles and had to be lowered by block-and-tackle.

The material collected by the expedition is particularly rich in rare specimens because the work was confined to geological formations in which very little work has been done heretofore. These are the Channel Sandstones, so called because the beds were formed by deposits filling stream channels worn in the clay surfaces in Oligocene times, probably 30 million years ago. The surrounding clay —now turned to shale—is softer and much more easily worked, and from it have come most of the Badlands specimens previously collected.

In the museum workrooms at the School of Mines, the specimens are being placed one after another on the "operating table." Each is protected by many yards of bandages which were soaked in a plaster of paris "soup." These bandages were allowed to stiffen before removal from the field, and furnished ideal protecting shells for the specimens. In the workrooms the bandages are first cut away, and the rocky matrix, which still partly envelops the specimens, is carefully removed with chisels, dentists' tools and scrapers. As areas of the fossil bone are exposed they are impregnated with a thin solution of shellac to harden them.

M. F.

THE PAPER-MAKING MACHINE AT THE FRANKLIN INSTITUTE

Paper has become a vital necessity in our daily lives. Without it, printing would be almost valueless, knowledge would be obscure, and countless industries would be at a standstill.

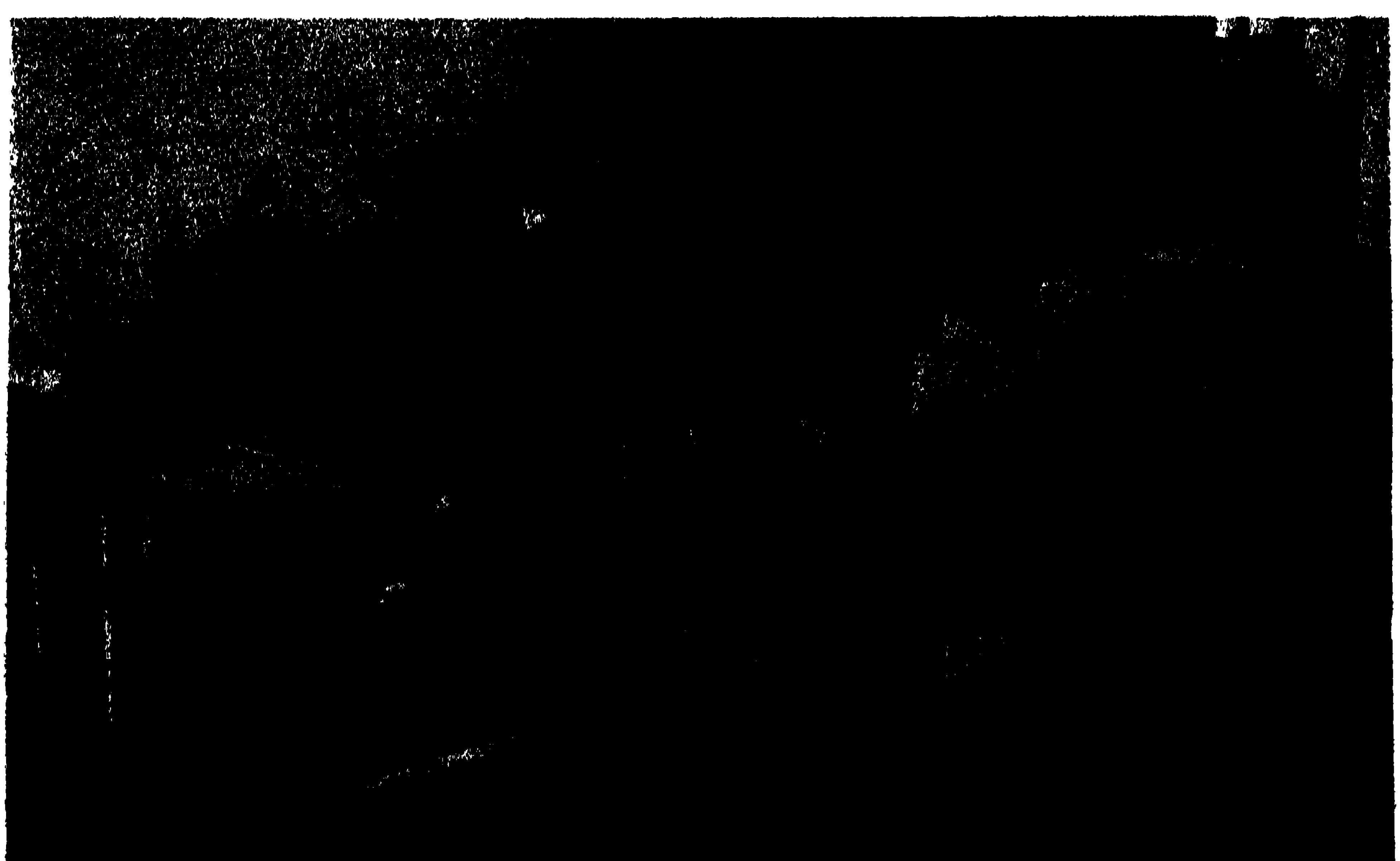
There are many people using it every day and depending on it for a livelihood who have never visited a factory or given a thought to how it is made. They have never watched the tremendous speed of the gigantic machines as they turn it out —a thousand feet a minute—two tons in a single day.

For those who know nothing about the processes of paper-making and do not live near a mill, the Franklin Institute in Philadelphia has on permanent exhibition a scale model paper-making machine of the Fourdrinier type. It is the only one of its kind in the world, and demonstrates to the visitors how paper is made in an easy understandable way, without even the confusion one might find in a large factory where just one of the thirty dryers is taller than the average man. This useful model is so small that all the stages of paper-making can be seen in a glance, and yet so large that each individual procedure can be carefully examined.

Gladys Müller

AN EXPERIENCED PAPER-MAKER DEMONSTRATING THE MACHINE TO FRANKLIN INSTITUTE VISITORS

Placed on a steel table eighteen feet long and four and one half feet wide, the machine makes five feet of paper a minute, eight and one quarter inches wide and can produce three or four pounds an hour. It is operated and controlled by push buttons and powered by variable speed electric motors. A mixture of wood pulp, soda and sulfite is used in the small beater, and the machine



Gladys Müller

SCALE MODEL FOURDRINIER PAPER-MAKING MACHINE

is complete with a motor-driven pump, miniature dryers and press felts.

Until the early part of the nineteenth century, paper had been made almost entirely by hand, but at that time a Frenchman, Louis Robert, and several other men were granted patents for paper-making machines. Shortly afterwards the invention was taken to England, where a new company, backed by two English stationers, Henry and Seeley Fourdrinier, began building machines in 1807 which were sent to other parts of the world bearing the name of the financiers.

In 1816, John Gilpin, of Philadelphia, took out patents for the first American paper machine, and examples of the paper he made on it were displayed at the opening exhibition of the Franklin Institute. Ten years later, Allen and William Curtis were operating two Fourdrinier machines, which they had purchased in England, at their mill on the Charles River.

Since those early days, the United States has taken the lead in the manufacture of paper, and now, just 250 years after David Rittenhouse started the first mill near Philadelphia, this country produces more paper than the rest of the world combined.

EMILY D. WALLACE

BOMBPROOF SHELTERS

NEARLY a year ago the American public was thrilled at the president's blithe reference to our producing 50,000 military airplanes per year and at Mr. Ford's alleged statement that he could manufacture 1,000 a day. Now bombproof shelters are called for with similar disregard for serious difficulties.

For a structure to be really bombproof its cover and sides must be of five to ten feet of reinforced concrete or its equivalent. It must be proof against poison gas from the outside, and it must have unfailing facilities for ventilation. It must have an unfailing lighting system, it must have water and sanitary conveniences with unfailing drainage to avoid drowning in case water pipes are broken, it must have a first aid station, it must have separate sleeping rooms for men and women, it must have telephone communication with the outside, it must have more than one exit, etc.

What about the cost of bombproof structures? For those that are really bombproof the cost has been estimated to be of the order of $100 per person, or about $66,000,000 for such a city as Washington. The enormous cost in money is only a minor part of the problem of providing bombproof shelters for our great cities. The diversion of skilled labor in their construction and the drain on materials essential for other purposes would disrupt any adequate defense program. If our forests were not so depleted we might take to the woods.

F. R. M.

ZWICKY'S SYSTEMS IN SEXTANS AND IN LEO

THE SCIENTIFIC MONTHLY for November, 1940, contains an article entitled "Problems of Nebular Research" written by me and illustrated by Mount Wilson photographs. Two unusually interesting dwarf irregular nebulae, shown on plates facing pages 399 and 401, are called "Baade's System in Sextans" and "Baade's System in Leo," respectively.

These designations are incorrect. They should be "Zwicky's System in Sextans" and "Zwicky's System in Leo." Both nebulae were discovered by Dr. Fritz Zwicky, of the California Institute of Technology, who identified them on photographs with the 18-inch Schmidt reflector, as objects which fulfilled his criteria for dwarf systems of the type in question.

Dr. Zwicky assembled a list of such objects for further investigation with large telescopes. Dr. Baade, with the 100-inch, verified the identification of the two systems under discussion and at the same time determined their distances.

The matter of nomenclature is important because these dwarf systems may play a significant rôle in cosmological theory. The regrettable error was called to my attention by Dr. Baade and Dr. Zwicky.

EDWIN HUBBLE

THE SCIENTIFIC MONTHLY

JUNE, 1941

TRENDS IN PLANT SCIENCE

By Dr. D. T. MACDOUGAL

DIRECTOR (RETIRED), DEPARTMENT OF BOTANICAL RESEARCH, CARNEGIE INSTITUTION OF WASHINGTON

THE dawn of the present century may be taken as the beginning of a new epoch in plant science. Farther back than this the impact of science on affairs was indirect and not easily to be appraised. Recognition of the fact that studies of plants from the view-point of the botanist might really concern agriculture, long delayed, came with a rush; the organization of the Bureau of Plant Industry, the members of which devoted attention to special phases of nutrition, cultivation, importation, selection and breeding of crop plants, and in development of methods of protection of cereals, fruits and tubers from the ravages of plant and animal enemies, was accompanied by an increase of personnel from a few dozen to several hundred within two or three years. Similar expansions in state experiment stations followed. Research facilities in universities and colleges were notably increased. The New York Botanical Garden came into full operation: the Desert Laboratory was established, and after thirty-six years of studies on desert vegetation is now concerned with closely related problems in soils and erosion, to which some attention had been given from the first. The publication of the results obtained by hundreds of researchers produced a flood of technical contributions for which new journals were started.

The experimentalist in the field or laboratory as well as the researcher in any branches of science soon found himself at a stage in which words of common usage could not express his findings, with the result that it was ncessary to coin new terms. This was the basis of the origin of the much ridiculed "jargon" of science. An article embodying a contribution to science is to be compared with a surveyor's description of a tract of land. The specifications must relate the location, include a calculation, define the boundaries of the area and make its lines close with those of neighboring similarly enclosed areas. Ideally its accuracy must be such that the nearest or next researcher or surveyor can start from these established corners to outline and define the boundaries of unmeasured areas beyond. Such articles are necessary to progress and are written for the guidance of other scientists and may not be capable of expression in common language. Like the field notes of a topographical survey of the Grand Canyon, they make but dull reading for the layman. These and similar writings are in effect a foreign language. They, however, are necessary in placing material facts on record.

Presently it became apparent that the subjects of these unreadable and frankly unliterary papers treated of many things of momentous interest to general welfare. It was in this stage of unfolding science that the war of 1914 opened. In the ensuing mobilization of the industries, scientists were asked to contribute individual expertness, not in finding out new things, but to apply what was known in promoting security and the general

welfare. The botanist turned his attention to the improvement of methods of breeding, cultivation and processing of plants and plant products.

A world-wide appraisal of national and local resources ensued. Personal participation in this survey brought to light the fact that while something like half of the copper in America was produced in the district in which the Desert Laboratory was located the production of food was but 12 per cent. of the needs of the population. The great remainder and most of the power necessary for its industries, farming and mining, were derived from fuel coming across three bridges over the Colorado River, a situation now duplicated with variations in a hundred regions on the map of the world.

The effectiveness of scientific methods applied in war as well as in peace was demonstrated. A general desire for more news about science led to the organization and endowment of Science Service in 1920, and to the addition of science editors to the staffs of many of the more important newspapers. Articles of fair precision dealing with current contributions were given adequate space sometimes on the front page; occasionally the paragrapher indulged in fantastic and startling headlines, but the actual news was available to the reader. The possibilities uncovered so stimulated the imagination of writers in this field, both laymen and technical workers were led into romanticizing current activities and to formulating prophecies, of which only fragments might be ever realized, and a lesser fraction within the span of any living person. This statement must not be taken to place all blame on newspapers and popular writings. Scientists joined in the glorification of contributions from laboratories and observatories, with almost complete disregard of the fact that new ideas recognized as important by a few thousand scientists or by a few hundred thousand intelligent readers may not become practically available to society in its adjustments to the swiftly moving developments in economics of the present day.

Here, as in all the disciplines of knowledge, results must in the first instance be made accessible to workers in the same and in adjacent fields by presentation with exactness, and with some attempt to arrange the new findings in perspective. The obligation to make available the implications of the widened knowledge thus achieved to the economist, the technologist, the sociologist, the statesman and to all forward-looking persons is not less binding. We can not persuade or compel their acceptance; to secure approval and utilization we must make our contributions of such weight, render our interpretations so clear and their pertinence to life so convincing that their adoption will be inevitable.

The originator of a new food product, new fabric or new motor or the statesman who develops an advanced plan of organization or administration does not stop with a simple announcement, but follows it up with continuing explanations and demonstrations of the manner in which the new idea may be utilized to individual and general welfare. The scientist is apt to recount his discoveries to a few colleagues, then toss them out the laboratory window to be picked up, used or abused by accident.

Two important considerations appear in any discussion of the relation of the scientist to the society of which he forms a part. First, it is to be said in repetition of a previous paragraph, that while unceasing efforts to publicize facts newly acquired in the laboratory, to emphasize their importance to the general welfare, or to raise warnings against weakness and dangers in current practices may be made many results of evident value must be available for long periods before they affect current practices. It is pertinent to repeat the trite pronouncement that if every person and all the people would follow definable and practical precautions all the major bodily ailments except

perhaps cancer and colds would dwindle into insignificance.

It was inevitable that cries of "Science is a failure" should have been heard in the economic crises of the last decade. If the scientist will continue to claim that he is "remaking the world" these outbursts are neither unmerited nor unjust. Now that the period of most emphatic censure of science and of scientists for their futility, and in a time when researchers of all kinds are being called from appointed tasks to collaborate in technological plans for the national security, Nobel prize winners, heads of departments in great universities, and research directors of great industries are indulging in optimistic prophecies and forecasts as to the benefits to be expected from current investigations. Pronouncements are shaped up into a ballyhoo, which discounts the possible, painful tedious advances of the next generation, and is an open invitation to the repetition of acrid disappointments which have recently been so freely expressed.

As a further prelude to the discussion of the subject of this article it should be kept in mind that science is essentially nothing more than systematized curiosity. Primarily it means that it devotees continuously seek to widen their knowledge of the world about them, first by simple direct use of their own senses and by experiments, using such tools and apparatus as may be necessary. No serious objection can be raised to this form of learning, and it is widely employed in education. Society has recognized the value of inquisitiveness in promoting culture, advancing civilization and in the development of industries. Laboratories, observatories and experiment stations have been founded, although never to a capacity to meet the full requirements of eager and able investigators.

Adequate or not, the obligation of the scientist is to make highest and greatest possible use of the facilities provided. The experimentalist must realize, however, that the enjoyment of his opportunities does not give him license to blow soap-bubbles. While no restriction can be safely placed on creative thinking, yet the tools of science find their proper function in securing results that will extend knowledge with implied alteration of current generalizations or which will open new vistas.

The following brief sketch of the current activities in laboratories devoted to plant science will serve to illustrate the nature of the problems under investigation. The diligent reader may decide for himself whether or not the facilities, expenditures and opportunities placed at the disposal of botanists, horticulturists, crop disease fighters and plant breeders have been profitably used for widening knowledge and to the economic advantage of society, which has provided them.

The recently observed centennial of the discovery of protoplasm and the recognition of the cell as the unit of living material—both conceptions antedating the recognition of the molecule as an entity—serves to emphasize the fact that at this time when the physicist is successfully concerned with the resolution of the elements into constituent forms of energy or matter, such as electrons, neutrons, protons, mesotrons, the physiologist is taking the living unit apart and variously manipulating its chromosomal particles. Once the elements or units of either living or non-living matter are thus taken apart, not all the king's horses nor all the king's men can put them together again.

There has recently come into the field of the physiologist a form of matter, known as the viruses, with such extraordinary properties and with such dread importance as destructive agents as to make necessary the erection of a new category of organisms. Virus units are now regarded as single large molecules of a proteinaceous structure. These may unite with or break down protoplasm of cells which they permeate readily, but unlike catalysts lose none of

their energy. Propagation is by incitation, not by fission as in protoplasmic action, as the single large molecule may cause the formation of myriad patterns of itself.

The plant pathologist, earlier concerned with the life-histories of fungi and bacteria and protozoa, which affect plants of economic value, now finds himself confronted with the still more serious problem of protecting crops against the ravages of these viruses, which have capacities for infection and damage widely unlike those of any organism previously encountered. Breeding of resistant strains, developments of immunities by methods of cultivation and sterilization of soils, seeds and propagules are practiced. Some of the features by which immunity may be provided by the plant are due to morphological characters, while others rest upon undiscovered or indefinable properties of protoplasm. Development of resistance to the viruses is the most difficult of all problems.

In the four decades following the appearance of Darwin's "Origin of Species," in which biologists indulged in voluminous essays on heredity, descent and evolution, with but little reference to living material, the Weissmanian hypothesis of the unalterable and unchangeable germ-plasm dominated all thinking, and not until experimental methods of study were fully adopted at the close of the century was it possible to escape from its thrall. The mutative departure in lines of descent as uncovered by the researches of the great Dutch botanist DeVries constituted the beginning of modern studies in genetics, the results of which have carried us as far away from that soporific dogma as has the use of the cyclotron from the old conception of "frozen" atoms.

Led by a note by Charles Darwin as to some "fool experiments" he had made in injecting chemicals into leaves with the idea of bringing about morphological alterations the author made some equally crude but successful attempts to modify egg cells by injecting zinc salts into pistils in 1905. Next Gager used radium emanations more exactly administered with more definite results. Many skilled experimenters using various agencies have since induced changes in the nuclear particles or chromosomes, which vary in number from species to species from a few to several dozen. These bodies undergo mitosis, splitting into pairs, the halves uniting with fragments from other units generally with final reductions so that the ultimate cells carry the initial number of chromosomes.

Exposure of cells during mitosis to various agents or unusual conditions of temperature may result in cells with multiples of the initial number of chromosomes, or the loss of some, may slow down the action of some or speed up the action of others, with consequent disjunctions, or may alter the insulating sheath of one so that it may be subject to an unusual disturbance by another. Now these particles are the actual physical bearers of the hereditary qualities, and the offspring arising from such altered chromosome complexes will not be like the parent plant and this unlikeness may be passed on to its descendants. Hybridization entails the union of particles derived from the chromosomes of unlike parents, and this action has long been utilized in securing forms with qualities of greater economic value.

Taxonomy or systematic botany has been for the past century the most completely static branch of botany. Classification of the elements of floras or the plants of newly explored areas and alterations in nomenclature have absorbed most of the energy of the workers in this field.

Species, instead of being regarded as unalterable lines of descent, are known to undergo changes from generation to generation based upon multiplication, loss or disjunction of chromosomes, induced by newly encountered conditions

or complexes of soil, seasonal variations, unusual radiations or animal cooperators. Many hundreds of species of seed-plants are now known which include races or strains with atypic chromosomal characters. The analysis of these and other complexities of genetic constitution promises the surest foundation for advance in studies of speciation and evolutionary derivation as well as for an intelligent procedure in the development of better fruits and grains.

Perhaps no function of plant life exceeds in basic interest the complicated process by which carbon dioxide of the air, water and nutrient salts are drawn in, bonded, compounded and made available to be transformed into living matter and all the complicated tissues and structures of organisms. Directly or indirectly such vegetable material is the food of all animals. The commonest substances of the soil are utilized. It is known that some rarer elements that are drawn up in the sap in minute proportions are necessary, but these, like potassium, magnesium and sodium, are widely distributed and are present wherever vegetation finds a foothold.

The entire process of carbon conversion is chiefly carried on in leaves or tissues containing chlorophyll and is known as photosynthesis. The dissociation of water or of carbon dioxide on catalytic surfaces by energy derived from absorbed light may be regarded as being a plausible generalization as to the nature of the process, yet it is to be admitted that the results do not conform to the pertinent mathematical equation.

The fact that a green plant may carry on the process for limited periods in darkness, and that a colorless flagellate, Chilomonas, has been demonstrated by Mast and Pace to be capable of carbon conversion and accumulation of starch, in a sterile culture of mineral nutrients in darkness and that a common mould, Aspergillus, uses carbon dioxide, suggests that protoplasm may have a fundamental capacity for the necessary catalyses, with whatever low level of energy may be available.

In the group of sulfur bacteria, including several genera and many colorless species, carbon conversion is carried on in darkness by the use of energy derived from the oxidation of hydrogen sulfide, a necessary constituent of their nutritive medium. The purple bacteria of this group carry a greenish "bacteriochlorin" (not related to chlorophyll) and a reddish carotinoid, which absorb energy from light and carry out carbon conversion.

The facts cited justify the inference that while protoplasm has a basic capacity for the assimilation of carbon, the necessary energy may have been derived from many sources in the evolutionary development of plants. that many light screens may have been used and discarded, that the pigments of the purple bacteria is an example of light-absorbent mechanisms, however numerous in the past, are now of limited occurrence, and that the chlorophyll apparatus, the prevailing type of sun-screen, makes available a comparatively enormous amount of radiant energy for carbon conversion in green plants.

That their entire supply of carbohydrates may be synthesized by chlorophylless seed-plants, when their underground parts are associated with fungi to form mycorrhizae has long been known. About two hundred species in the heath, orchid, gentian and triurid families are devoid of green color. Their supply of carbon may be derived from humus products through the cooperating fungi, and the possibility is not excluded that the simpler carbon dioxide may be utilized. All forest trees have mycorrhizal root-systems and derive a considerable share of woody material in this manner. Here as in the case of nitrogen fixation by plants with root-nodules containing a symbiotic rhizobium the possibility that the bonding of this simple and important element may be carried out by the protoplasm of the

higher plant is heightened by the fact that some researches have yielded evidence that nitrogen fixation may be accomplished by seed-plants.

Alteration of perspective to bring basic capacities of living matter into the foreground and development of new instruments and methods of research, including the use of radioactive isotypes, the electron microscope and fresh technique in cytological experimentation, may be expected to rescue the problems in carbon conversion and nitrogen fixation from the stalemate in which they now are found.

Protoplasm has a capacity by which it draws into its mass a wide variety of substances of inducing chemical combinations beyond those implied in photosynthesis and of converting the resulting material into the colloidal state characteristic of living matter. Such accretions are the essential feature of growth. Increase in size has been the subject of innumerable observations. By compilation of measurements of rates of increase a curve has been plotted expressing the fact that in the growth of any unit, any organ or any individual plant or animal the rate is at first low, then quickly rises to a maximum, after which it falls off very gradually. In the case of many perennial plants growth continues during the lifetime of the individual, which may be as long as three thousand years in the big Sequoia of the Sierra Nevada.

The newer researches on growth have been concerned with analysis of the physical conditions which make for the accretions to, depletion or repletion of the protoplast or of its organs, and to a study of the morphogenic procedure by which cells in the latter part of their curve of growth may undergo differentiation into the tissues. So great is the activity in this field that a society has been organized to promote ready communication among the workers engaged and to support a journal for the publication of pertinent contributions. While both zoologists and botanists have conjoined in this movement it is conceded that the generative cells of plants offer the widest variety of opportunities for experimental study.

This last consideration applies with especial force to auxins or growth-promoting and growth-inhibiting substances, vitamines and respiratory ferments, which may originate in one part of the plant and be translocated to another, or which, as in the case of most trees, may be derived from the organic matter in the soil or may be furnished by cooperating fungi with which the roots form a symbiosis as in mycorrhiza.

The action of these substances has been compared to the secretions of the ductless glands of animals with but slight enlightenment. As they are translocated from the region of origin to neighboring tracts much after the manner of other organic material their designation as hormones is also misleading.

The growing points of stems and roots are of primary generative cells, the growth of which results in increase in length. Increase of thickness is produced by the division of growth of secondary generative cells. The two tracts differ in their properties so that the indolic acids simulating "auxins" checks or inhibits the activity of growing points in buds or roots and thus prevents elongation, while cambium or secondary generative cells are stimulated. Growth in length is facilitated by vitamines and by several mineral elements derivable from soils. The conjoint activity of many of these substances is responsible for the orderly precession of organ-formation and for the completion of the processes of differentiation of cells into tissues, such as vessels, tracheids, fibers, sieve cells, cork, etc. Such a well-knit program would result from growth-promoting substances originating with the plant. However, when the roots of long-lived perennials such as trees are furnished growth-promoting substances as usually occurs in mycorrhizae, by fungi

or other organisms in the soil, seasonal growth may be initiated weeks or even months in advance of any possible supply from the shoot.

Some of the tropisms by which stems bend toward or away from sources of radiant energy or in direct or negative response to gravity make the implied curvatures by unequal growth caused by localized formation or accumulation of "auxins." A wide variety of useful practices in culture and development of economic plants has been made possible by researches on growth, as regulated by auxins, vitamines and "trace" mineral elements.

The results cited above may be taken to exemplify the content of thousands of contributions which embody the trend of investigation of the nature and action of organisms. The solutions of the problems obtained afford a basis for a better comprehension of the world of plants and animals and make possible a more intelligent adjustment by man to his place in nature. A material part of this adjustment finds expression in improved methods of agriculture in both plant and animal industries.

About four thousand million acres of land surface may be profitably utilized in agriculture. While the population of the globe has doubled within the last eighty years to a total of well over a thousand million, the application of well-known biological laws makes it highly improbable that there will ever be as many as two thousand million people alive on the earth at any time. Agricultural products year by year and every year have shown a surplus, although local failures of crops have resulted in famines before supplies could be moved into the stricken area.

Application of available knowledge as to growth, breeding and culture could be made to increase the yield two or even three times. Although these facts constitute a guarantee of material security, to be recalled in any attempt to unsnarl tangled economic conditions, their recapitulation by no means includes all the factors to be taken into account. Certain technological activities, political and sociological developments, present a much more complex problem for which an equation has not yet been found.

Only reluctantly will scientists admit that any technological program is not beneficial in all its effects. It is assumed that any new mechanical device or that any new conversion of material to another use is justifiable and contributory to the general welfare. Researchers whose pronouncements in their own fields of investigation are widely accepted will naïvely but boldly allege that new automatic machinery, new processes and all alterations in the use of basic raw materials are immediately beneficial. Nothing could be more fallacious. A new textile, a new alloy or a new plastic may impair the welfare of the inhabitants of regions widely distant. Two or three generations may live out their lives under stress before readjustment is made. "Survival of the fittest" is a fairly benign idea in comparison.

The plant scientist in the laboratory and his collaborators in the experimental field can sustain the plea of not guilty to this lack of comprehension of the serious consequences of diversion of raw materials.

Early in the period during which a rapid increase in population occurred three fourths of everything used or consumed was derived from the fields, forests or from animals supported by them. Despite varied utilization of wastes, with no deficiency even with the enormously increased population, this proportion has now fallen to about one fourth. The products of the coal-fields, oil-wells, quarries, salt deposits and mines are now being drawn upon heavily and processed to meet the requirements of material for tools, implements, machinery, power, textiles, houses, dyes and a vast array of compounds used in food, medicine and the industries. Three

fourths of human wants and needs are met by this material at the present time.

The stores of material thus drawn upon were accumulated in long geological periods, and would be replaceable only by a repetition of the conditions under which they were laid down. Whether these deposits may be exhausted within a hundred or two hundred years is debatable. But presumably, since they are measurable, they are not inexhaustible. In their uncontrolled exploitation, accumulated savings are being used, while possible annual income from the farm and forest are neglected. It is true that much attention has been given to processing of surpluses of organic material such as sugar, starch, wood, cotton, beans, potatoes, fruits, hulls, stems, etc., but the portentous proportionate reduction in the use of farm products prevails.

Greatly contributory to the condition implied are the political conditions which in connection with wars has started movements toward nationalization of industries. The present tendency is to the effect that every country should develop substitutes or find new sources for the raw materials ordinarily received in free commerce from other regions in which they can be produced most readily. In statements as to the adequacy of the replacements carelessness as to qualities and expense is of the commonest occurrence. Conclusions as to the failures of science may sometimes be traced to extravagant and inaccurate claims made by technologists and inventors. As an example it is to be said that since this manuscript was begun a false claim has been made that compounds have been found that may be used successfully in combating malaria instead of quinine, the principal supply of which is now processed in Java. Such a claim is not supported by reliable medical authorities.

Another dangerous delusion as to substitutes for rubber is being widely publicized. A number of plastics have been made in the laboratory which have some of the properties of the plant product. One is made mainly from derivatives of crude oil. A few may be used in motor tires. All are laboratory products. None may be compounded in a factory as economically as plantation rubber. Possession of the formulae for such material is valuable and might mean much for national security. Their production and use for special purposes to which they are better suited than rubber is of course justifiable on fundamental economic grounds. But since the consumption of rubber is steadily increasing at a rate which will soon reach twelve pounds annually per capita it is important that widely distributed sources of supply, as in the case of sugar, be maintained at all times. The areas in which this material may be grown might be extended many times without infringing on land suitable for the production of staple foods. The survey of tracts suitable for rubber in Brazil, Guatemala and elsewhere by the U. S. Department of Agriculture can be applauded as a wise measure although somewhat belated.[1]

Not all the featues of unbalance can be attributed to the blind zeal of technologists, however. It is a well-recognized principle in most industries that over-production should be avoided. No such rational procedure is to be expected in the greatest of all industries, agriculture. For example, with the annual production of cotton at all times adequate to the world's needs, including all con-

[1] The above considerations also apply to guayule, the rubber derived from *Parthenium argentatum*, a small shrub native to northern Mexico and western Texas. A million pounds of raw rubber is turned monthly from wild shrub by factories in Mexico. About ten thousand pounds can be produced daily by the factory which processes plants from an experimental plantation of several thousand acres at Salinas, California. The successful domestication of this plant and the development of strains in which rubber constitutes 21 per cent. of the dry weight of harvested material is a noteworthy agricultural accomplishment. "Emergency rubber" can be secured in one year after germination of seeds and profitable crops in three or four years.

versions, and with millions of bales of surplus stacked in yards and warehouses from the Imperial Valley to South Carolina, in Mexico, Egypt, Mesopotamia, Nigeria, India and elsewhere, heavier plantings are made. Here as in medical science practice of known facts would abolish important economic illness.

The scientist has no power by which he may implement his disapproval of this blundering procedure. By the application of the results of his researches improved strains of many kinds of plants have been selected, bred or imported; varieties suitable for different climates, regions and populations have been selected, and a never-ending fight in protection of crops carried with notable successes, so that there is now and may forever be food and clothing adequate to insure the comfort and welfare of whatever thousands of millions of people are to be supplied. It is only necessary that such material move freely and speedily from the plantation to the consumer. It is to be admitted, however, that these efforts of the scientist, by the results of which famine in any part of the world might easily be averted, have contributed in no small degree to major disturbances in an economic system based in part on barriers to distribution, shortages in manufactured products and the nearness of want. Admission of guilt to such an indictment is accompanied by no feeling of shame. It is to be pleaded in extenuation that the physical standards of living have been raised, the enrichment of culture promoted and a wider awareness of the world about us achieved.

Since research, invention and technology in general is fraught with such serious possibilities, it will be of interest to note the current activities of the plant scientist.

The centennial of the discovery of the cell, as the unit of living matter, finds him deeply engaged in an analysis of its organization; in the study of the interplay of its minute parts by which the hereditary characters of the plant or animal are transmitted from generation to generation with attention to the incidental and experimental combinations or modifications of these characters. The specific influence of the enzymes, vitamines and auxins, and the nature of the viruses are to be determined. The physical procedure by which the ordinary substances of the soil, air and water are drawn into the cell and transformed into the colloidal states of protoplasm are not to be regarded as understood until they are capable of being expressed as mathematical equations the minor factors of which are being diligently sought. The power by which these operations are carried out is derived by oxidation of organic substances the formulae of which are yet to be framed satisfactorily. Still more remote is the fundamental capacity of protoplasm by which bonding in nitrogen and of carbon is carried out in its complex colloidal mechanism. The conversion of both of these all-important but inert elements is increased by supplementary processes in the higher plants. Nitrogen fixation is markedly facilitated by the symbiotic cooperation of a bacterium in root-nodules, while carbon conversion is enormously accelerated when radiant energy is made available by the screening action of chlorophyll or other pigment, the process then being known as photosynthesis. The included reactions present some baffling problems to the physiologist. Since these two phases of activities of plants are vitally necessary to the existence and continuance of life they are due to receive increasing attention from researchers who employ new reagents as their effects become known, the products of the cyclotron as they become available, new angles of approach as they give promise, and new designs in apparatus such as the electron microscope when they enable the inquirer to delve more deeply into the nature, structure and operation of living matter.

MAUPERTUIS, AND THE PRINCIPLE OF LEAST ACTION

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Every action of nature is made along the shortest possible way.—*Leonardo da Vinci.*

THE principle of least action was discovered by Maupertuis in 1744. Three great mathematicians—Euler, Lagrange and Sir William Hamilton—contributed to the development of that principle. By the end of the nineteenth century, it could be said that the whole science of mechanics rested on this same idea. At that time, undreamt-of things lay ahead: relativity and the quantum theory were just around the corner; the mechanics of Newton failed completely within the atom; least action seemed also to fail, and then, by a sudden transformation, became the cornerstone of the new "wave mechanics" which embraces all the old mechanics and the new as well. It is not strange that the principle of least action is sometimes regarded as the greatest generalization in the realm of physical science.

In its technical sense, the term "action" is not recognized by the dictionary or encylopedia. It is foreign to library catalogues. The principle derived from it is known only to a small group of scientific specialists. Clearly, some explanation is needed to reconcile the absence of all general understanding of this subject with the fact of its surpassing importance.

There are three reasons for this strange situation. First, the idea of *action* is difficult to explain, as will, perhaps, be demonstrated in the course of this article. Secondly, the advantages of the principle, as applied to the solution of mechanical problems, were far from obvious. It has taken two hundred years to recognize its possibilities. Thirdly, the mathematical difficulties of proving that action tends towards a minimum, as distinguished from an extremum (either a maximum or a minimum), were for many years incapable of a satisfactory solution.

The author of this principle, Maupertuis, was one of the scientific leaders of the eighteenth century. His own peculiar genius and remarkable energy, combined with a dramatic environment, gave his career a contemporary fame which has seldom been equalled. To-day, he is practically unknown, or is remembered only as an object of ridicule and contempt. If the principle which he discovered has waited overlong for recognition, there is a striking parallel in the fate of the author.

The simplest way to approach the principle of least action is to consider, first, some human traits which do not seem connected with abstract science. In our daily lives, particularly in our work, we strive as far as possible to "save time and energy." The expression is a common one. Let us look at this from a new standpoint: which of the two, energy or time, are we most anxious to save? Are we willing to expend a vast amount of energy, provided that our results are accomplished in a very short time? Or would we rather take an exceedingly long time, provided that the expenditure of energy is sufficiently small? The first calls for great power, or energy per unit of time; the second calls for a great quantity of time per unit of energy. There is no recognized name for the latter concept. We shall call it "rewop"

(pronounced, rew-op). The derivation will be easily recognized since, in a sense, rewop is the opposite of power. All of us have known people who are inclined to be a little rewopful.

If we examine the laws which prevail in the physical world, we find that whenever there is more than one conceivable method of operation, nature follows the one in which the product of the time multiplied by the energy is the least possible amount. Simple as this seems, it is the key to the solution of all mechanical problems. We have expressed it in mathematical form. It is merely another way of saying that nature saves both time and energy, but that she has no preference between the two. Great power or great rewop—it is all the same. She would just as soon save time as energy.

There are many concepts similar to the idea of energy multiplied by time. Momentum is one. It is mass multiplied by velocity. To grasp these concepts is difficult for those who do not deal constantly with such things. On the other hand, it is easy for an engineer to think of momentum. Usually, he will not even care about the mass or the velocity, separately. What he needs is the product of the two, expressed in centimeter-per-second-grams or similar units. He deals with forces; and this is the measure of a force: rate of change of momentum.

Few of us can remember the time when we took our first tottering steps; walking upright, with great care and concentration, on our two legs. Before we could do that, we must have acquired, somewhere in the back of our heads, a very fair idea of momentum.

It is different with energy multiplied by time. We have gotten along quite successfully in the past without this idea; as a consequence, our minds are incapable of fusing energy and time into a single concept. The first step, of course, must be to find a word for this unfamiliar quantity. Unfortunately, it already has a name—action—and no more unsatisfactory name could possibly have been chosen. What are we to think when a million kilowatt-hours of energy delivered in ten minutes is called "action"; and ten kilowatt-hours delivered in a million minutes is likewise called "action,"—and the same amount of action! It was no slight scientific disaster when we missed our chance of calling this quantity "entropy" or "enthalpy" or some other incomprehensible word.

The difficulty of grasping this new, or rather this old, concept which we must now call "action" cannot be exaggerated. One of the two or three books in English which go into this subject thoroughly was written by the great English physicist, E. J. Routh. He states that a function representing action "expresses the whole accumulation of *vis viva.*" He must have known that the whole accumulation of *vis viva* (an obsolete term for kinetic energy) is still nothing more than *vis viva,* or energy; while action is energy multiplied by time.

Was Routh's mistake a mere oversight? If so, it is strange that Heinrich Hertz, the great German physicist, should have made the same blunder. Hertz writes: "It is difficult to see how the summation of energies existing at different times could yield anything more than a *Rechnungsgrösse.*" This is the German word for: an artificial quantity which is perfectly useless except for practice in arithmetic. Notice again the same idea of a summation of energy, when he was really dealing with an accumulation of action. This emphasis, placed on energy, is fatal to an understanding of action. It is a mistake we are prone to make. In our ordinary use of the term "power" we think of energy first and time second, although each has an equal share in this concept. It was for this particular reason that we in-

sisted on the obvious fact that power is not more essential than its own inverse, rewop. Whatever else action may be, it is a partnership of time and energy in which neither can be emphasized a shade more than the other.

For a truly profound insight into this matter, coupled with prophetic vision, we have the words of Thomson (Lord Kelvin) and Tait, written in 1879: "Maupertuis' celebrated principle of *Least Action* has been, even up to the present time, regarded rather as a curious and somewhat perplexing property of motion than as a useful guide in kinetic investigations. We are strongly impressed with the conviction that a much more profound importance will be attached to it, not only in abstract dynamics, but in the theory of several branches of physical science now beginning to receive dynamic explanations."

It is not my purpose to go into the present-day theory of least action. Indeed, the story of Maupertuis, himself, now demands our attention. But before leaving the scientific phase which is inseparable from the biographical, some account must be given of how this remarkable prophecy of Thomson and Tait has been borne out in the new quantum theory.

Planck discovered that radiant energy (light, heat, and electricity) seems to travel in little units, or packets, of energy, called "quantums." Each particular radiation has its own rate of vibration,—so many cycles or kilocycles per second. The energy in a quantum is not the same for waves of different frequency, but if we multiply the energy in a quantum by the corresponding time it takes for one complete vibration, the surprising fact is disclosed that in every case the resulting action is the same amount. This definite quantity is 26-zeros-65420 erg-seconds of action; or 39-zeros-1817 kilowatt-hour-seconds. It is called Planck's constant.

Heretofore, we may have been haunted by the idea that there is something artificial, something unreal, about the concept of action. Planck's constant is the crowning proof that Maupertuis's discovery pertained to something universal and everlasting. The fundamental nature of this concept is further attested by the fact that action is not relative. It is one of the few quantities which was left untouched by Einstein's Theory.

We come, now, to the man, himself: Pierre Louis Moreau de Maupertuis was born in Saint-Malo, in 1698. Coming from a family of wealth and position, he was able at an early age to devote himself to the study of science. At the age of twenty-five he was admitted to the Paris Academy of Science, chiefly by reason of original work in mathematics. He went to London, in 1728, the year Newton died, and became a member of the Royal Society. Thereafter, he became an ardent supporter of the Newtonian theory of gravitation, which was violently opposed in France, where the ideas of Descartes were considered invincible.

In 1730, Voltaire wrote a letter to Maupertuis, full of the lavish compliments of the period; praising his scientific achievements, and asking for Maupertuis's confirmation of Newton's theory. Afterwards, the two met and were friends for twenty years; together they were responsible for the final acceptance, in France, of the Newtonian theory. Maupertuis was appointed by the King of France to lead a scientific expedition to Lapland, where he measured an arc of the meridian for the purpose of proving that the earth is flattened at the poles, as Newton had predicted.

I have made little attempt to show the color and romance of a career which had already acquired unusual interest. I now approach a drama as strange as any in the annals of science. Two of the characters have already been introduced; the third was Frederick the Great of

Prussia; and the fourth was Samuel Koenig, professor of mathematics, a native of Switzerland.

Upon Voltaire's recommendation, Frederick the Great invited Maupertuis to take the office of president of the new Berlin Academy of Science. Maupertuis accepted the offer and went to Berlin in 1740. Four years later, he published his first account of the principle of least action.

It is significant to find that his discovery was made in connection with the theory of light, and was later applied to mechanics. Years afterward, Sir William Hamilton, recognizing the analogy between light and mechanics, developed in a brilliant manner the mathematical correspondence between the two. His results were not fully appreciated until 1924, when Luis de Broglie published his astounding theory of wave mechanics. Strange to say, Maupertuis—the man who helped to overthrow the Cartesian theory of gravitation—was himself deceived by Descartes's absurd paradox that light travels fastest through the densest medium; and, starting from this wholly erroneous premise, he made his greatest discovery.

In 1746, Maupertuis presented his mechanical theory of least action. Immediately, a controversy arose concerning the new theory, in which Maupertuis found himself opposed by a former friend and fellow student, Samuel Koenig. There were, of course, others who denied the importance and truth of the new theory; Koenig, however, claimed that not only was the theory based on erroneous conceptions, but that Leibnitz had developed the same idea, long before his death, and had communicated it in a letter to Hermann. This letter, according to Koenig, had fallen into the hands of a certain Henzi, from whom Koenig had obtained a copy. He presented a fragment of this copy to the Berlin Academy, and later sent a copy of the entire letter to Maupertuis. Naturally, Maupertuis demanded to know where the original letter could be found, or what evidence there was of the authenticity of this copy; which, if it were genuine, proved conclusively that Leibnitz had anticipated his own discovery.

Unfortunately, Henzi had since had his head cut off, having been convicted of treason to the state; and Hermann had preceded him to another world. Koenig was therefore without witnesses; and was unable to offer any suggestions as to where the original letter might be found. He confined his exertions chiefly to an attempt to prove that the theory was erroneous and without value. Maupertuis then put the matter before the Berlin Academy, and a formal demand was made upon Koenig by the Secretary to produce the original letter or other satisfactory evidence. Months passed, during which searches were made, at the instigation of the Academy and of Frederick, to discover any possible trace of the letter among the papers of Leibnitz, Hermann, or Henzi. Meanwhile, Voltaire took up the quarrel on the side of Koenig.

There are two cardinal points which must be understood in connection with this famous episode. The first is, that Maupertuis's title to fame for the discovery of least action was not even challenged. Had Koenig succeeded in proving the authenticity of his copy, it would not have detracted from the brilliance of Maupertuis's achievement. As he was the first to publish, his place in history is secure. Newton and Leibnitz, for example, both discovered the integral calculus; the two men were therefore of equal genius in this respect. Newton, however, was first to publish, and consequently deserves to be mentioned first in connection with this branch of mathematics. Napier is still the discoverer of logarithms, although the Swiss, Bürgi, made the same discovery at almost the same

time, and published his results six years after Napier.

The second cardinal point is this: From the nature of the circumstances, the burden of proof rested squarely on Koenig. He made the attack. Maupertuis could not by any conceivable form of logic disprove his positive assertion. To do so would be to prove a negative. Consequently, Maupertuis had every right to demand some evidence aside from Koenig's unsupported word. Even though Koenig's chief witness had so completely lost his head, it still rested entirely with Koenig to refrain, or not, from an undertaking which profoundly affected the lives of all concerned, and did irreparable damage to Maupertuis's name.

Six months after the formal demand of the academy was made, no satisfactory reply had been received from Koenig. The academy then published a formal *Exposé* of the affair, signed by all the officers (except Maupertuis) and other members. Koenig was accused of an unjust attack upon Maupertuis's reputation. and it was declared manifest that the copy had been "forged." Koenig resigned voluntarily from the academy.

It may appear that the word "forged" was too strong. It has since led to the greatest confusion, and to make matters worse Maupertuis stressed the fact that the copy of the letter sent to him by Koenig did not agree, in an essential point, with the copy presented to the academy. As it turned out, this has so beclouded the issue in later years as actually to injure Maupertuis's cause.

Any one who has followed the argument thus far will recognize that Koenig was not charged with altering an original document or imitating another's handwriting. The word "forge," as well as the French word from which it is derived, means "to produce or devise that which is untrue or not genuine"; literally, to fabricate in a forge. In this sense, whether justly or not, Koenig was accused of having forged the copy of the Leibnitz letter. It must be evident, however, that even if the copy were genuine, no man of judgment, or with a sense of justice, would have made use of it, in the circumstances.

The facts so far related are easily proved. There are in existence in the United States at least a dozen different volumes, printed at the time, which give the letters which were exchanged, and the arguments on both sides.

Nevertheless, another version of this story has come down through two centuries—a version which owes its origin to Voltaire, and may be called the poet-philosopher version. Thomas Carlyle, in his strange and wonderful "Life of Frederick the Great," added his own unique seal to this account of the affair. In modern times, indeed as late as 1936, Alfred Noyes has given us once again the poet-philosopher version. In his "Voltaire," he writes:

> The younger philosopher, Koenig . . . thought that Maupertuis was mistaken. The principle was untrue, he said, and the idea was not new. Leibnitz had discussed it in a letter of which he had a copy.
>
> Maupertuis, who really does seem to have developed a more than Prussian arrogance, determined to crush the younger man out of existence. . . . He summoned the academicians whose salaries were paid by him. He told them that Koenig had forged a letter by Leibnitz; and on the strength of his presidential position he induced them forthwith to deprive Koenig of his membership of the Academy. . . . At this moment Voltaire quietly lifted his hand and made his own first move. He began by publishing a quiet and courteous letter in defense of Koenig, simply but very clearly describing the act of despotic injustice committed by Maupertuis, and at the same time deftly pricking the bubble of his great discovery.

It is, of course, impossible to reconcile an account such as this with the one previously given. However, we may dismiss with a smile the closing remark about "deftly pricking the bubble of his great discovery." Alfred Noyes, poet, can

hardly be expected to know much about two-hundred years of scientific history, of which most scientists are ignorant. It is difficult, however, to understand why two such cardinal points in favor of Maupertuis as we mentioned earlier escaped his attention—two points which, together, make his cause futile and his logic worthless.

Voltaire's letter was answered by a letter from Frederick, himself, in defense of Maupertuis. Then, in 1752, Maupertuis published his "Lettres" which did not pertain to this quarrel, although there is a reference to it. The Letters were, rather, a collection of various scientific studies intermingled with highly imaginative speculations which were written, perhaps, somewhat in the spirit of H. G. Wells. Some of his ideas have since been brilliantly confirmed; others verged on the absurd. This gave Voltaire his great chance, and he was quick to seize it. In the same year, he published what Noyes calls "the most devastating satire of the century"—the "Diatribe of Doctor Akakia."

Macaulay has said that "of all the intellectual weapons which have ever been wielded by man, the most terrible was the mockery of Voltaire." A perusal of "Doctor Akakia" bears witness to that fact. The full force of this terrible power was directed upon Maupertuis in an unmerciful and unscrupulous deluge of irony.

One of the consequences of "Doctor Akakia" was that Voltaire broke with Frederick and left the court of Berlin, never to return.

There are certain facts which lead one to believe that the much-disputed Leibnitz letter may, indeed, have been authentic. Leibnitz was familiar with the idea of action, as Maupertuis readily acknowledged. Even at that time, the term "action" was criticized as being wholly inadequate, and Maupertuis wrote "that having found this word already established by Leibnitz and by Wolff . . . I have not wished to change the term." According to D'Alembert, it was Wolff who first conceived of action.

Leibnitz apparently made no use of the idea of action, unless it was in an attempt to develop a theory of the conservation of action, similar to the conservation of energy. Many people have tried to prove that he conceived of the idea of least action. None of them support this by actual reference to any of his published works or recognized letters. Within the last few years a French philosopher, after profound study, has come to the conclusion that even if Leibnitz did not actually write the letter presented by Koenig, it was at any rate exactly the kind of a letter he would have written. Henceforth, he refers to this letter as a proved fact. Few of us, however, would be willing to go to this extreme. It seems certain that if Leibnitz did write the Koenig letter he must later have abandoned the idea of least action as unsound.

There is one question concerning this subject which has never yet been adequately answered. What motives led Voltaire to turn with such fury on a friend he had known intimately for twenty years? The violence of his attack seems out of proportion even for the crime of which Maupertuis was conceived guilty. Indeed, Voltaire's ridicule did not entirely cease after the death of Maupertuis, in 1759.

Koenig seems to have been a man of sincerity and high purpose. Voltaire's fame is founded on his love of truth and courage in defense of truth. Carlyle's passion for honesty and justice is the key to his whole character. Noyes has an equal regard for the same everlasting principles. Were they not all, however, deceived into thinking that Maupertuis's discovery was an idiotic piece of nonsense, and hence that he was not entitled to the amenities of civilized warfare?

We turn now to a consideration of more recent times. The present attitude towards Maupertuis, however, can be understood only in the light of this ancient quarrel with Koenig. Voltaire's irony has been more dominant than the supposedly clear and dispassionate record of the scientific historian. The scant mention—if any—which is granted to Maupertuis usually carries with it a faint but unmistakable note of scorn.

A favorite accusation which has been repeated with parrot-like regularity is that Maupertuis was so engrossed in metaphysical speculations that no clear meaning can be attached to his vague and mist-like conclusions. As a matter of fact, he was far in advance of most of his contemporaries in this respect. It would be difficult, for example, to find a more modern or clearer expression of the relation between science and metaphysics than the following words, taken from an English translation of Maupertuis which appeared in 1734. They give also a glimpse of the intellectual pains, long since forgotten, which accompanied the startling idea of universal attraction:

> If bodies still continue to gravitate towards each other, why may we not investigate the Effects of this Gravitation, without diving into the cause of it. Our whole Business will then be to enquire whether or no it be true that Bodies have this Tendency towards each other; and if we find the thing to be a fact, let that content us for our deductions with respect to the Phænomena of Nature; and let us leave it to sublimer Philosophers to search into the Cause of this Tendency. . . . But some of those who reject Attraction, look upon it as a Metaphysical Monster and believe its impossibility so fully proved that however Nature might seem to favor it, it were better to acquiesce in total Ignorance, than to make use of so absurd a Principle.

With regard to least action, Maupertuis makes it perfectly clear that in this case, also, his essential Business is to enquire whether or no it be true.

E. T. Bell once wrote, with regard to a certain algebraic expression, that anyone who could look at it and not be at least mildly surprised must be an "algebraic imbecile." In the same way, one must be a metaphysical moron not to recognize the implications of the principle of least action for a divine Providence with which science, officially, cannot be concerned.

Some such argument as this is necessary to excuse the earlier part of this article where no attempt was made to escape a metaphysical explanation of least action, although care was taken not to spell nature with a capital "N."

A more serious criticism of Maupertuis is that even apart from metaphysics, he had no adequate conception of his own discovery, and that his applications of it were merely trivial. There is, apparently, only one book in English (a translation from the German) which gives an account of the three problems which Maupertuis worked out to illustrate his principle. We refer to Mach's classical "Science of Mechanics." It is far better, if one can do so, to read Maupertuis's own words which give in concise, lucid style his applications of least action to inelastic impact, elastic impact, and the principle of the lever.

If Maupertuis's works are not available, however, Mach's book gives a fairly good outline of these three cases. His conclusions, nevertheless, as to their importance, and as to the importance of least action and Maupertuis's contribution thereto, are entirely wrong. They will ultimately be recognized as the most glaring imperfections in a book which betrays unexpected limitations in more than one respect.

To show how far Mach was from grasping this particular subject, he attempts to belittle the importance of least action by referring to another principle of mechanics which is equally powerful; namely, Hamilton's principle. This principle well deserves to be called after the great Irish mathematician, but it is

an "action" principle. "Hamilton's function" has the dimensions: energy multiplied by time. Hence Mach has merely shown how the principle of least action was in later years to be recast into another and perhaps more significant form.

It is uncommon to find a modern author who recognizes the importance of Maupertuis's analysis. One of the few who have done so is Richtmyer, who writes in his "Introduction to Modern Physics": "Nearly two centuries ago, by a line of reasoning which would have done credit to the Greeks, Maupertuis proposed the law of least action."

There seems to be a general impatience with Maupertuis because he failed to equal his friend, Euler, as a mathematician and could not compete with men who came after him, like Lagrange, Jacobi, and Hamilton. There seems also to be much present confusion about the origin of least action. We read of Euler's principle of least action; of Lagrange's; of Hamilton's; and—perhaps the very latest—of Fermat's principle of least action. Fortunately they are all the same. There is only one, and that is the one of which Maupertuis wrote:

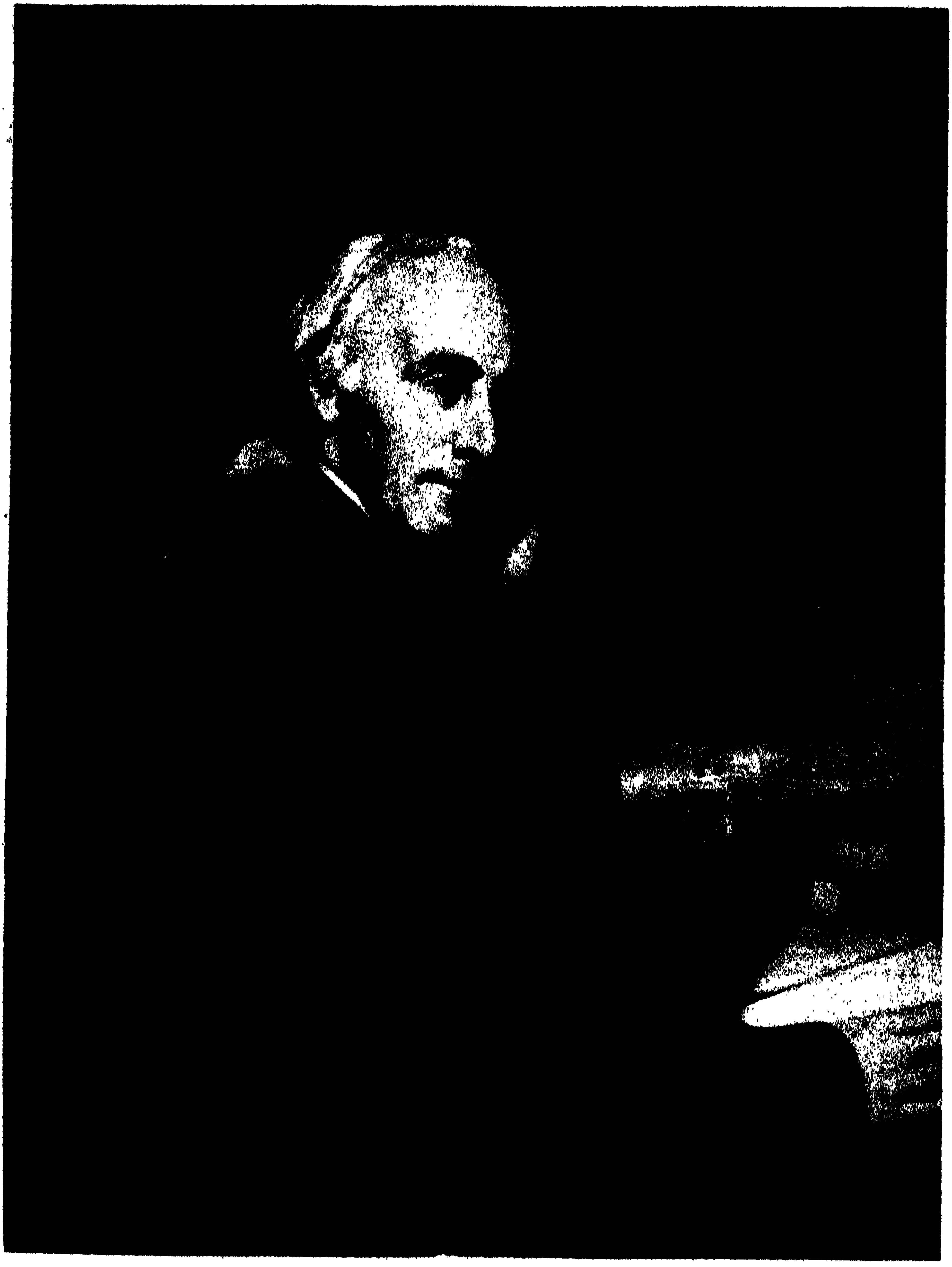
There is a principle truly universal, from which are derived the laws which control the movement of elastic and inelastic bodies, light, and all corporeal substances; it is that in all the changes which occur in the universe . . . that which is called the quantity "action" is always the least possible amount.

THE ANOPHELES GAMBIAE MOSQUITO IN BRAZIL

THIS dreaded malaria-carrying insect, a native of Africa, was first discovered in Natal in 1930 by a member of the staff of the Foundation. Apparently it had come in an airplane or on one of the fast French destroyers which at that time were serving the French air line between Dakar in West Africa and Natal in Brazil. The alarming spread of this African scourge in northeastern Brazil and the virulent character of the malaria which it produced resulted in a systematic campaign carried on by the personnel of the Foundation in collaboration with the Brazilian Government. Dr. Fred L. Soper, representative of the Foundation in Brazil, has been in charge of the direction and administration of the offensive, and a staff of over two thousand doctors, technicians, scouts, inspectors, guards and laborers have been enlisted in the battle.

A year ago we reported that the gambiae had been pushed back to its central strongholds in the main river valleys and on the narrow coastal shelf of northeastern Brazil—an area of perhaps twelve thousand square miles. Around this area a line of fumigation posts was erected to keep the mosquito from breaking through into new territory, and a concerted advance was begun to narrow still further the boundaries of its domain. The weapons employed were Paris green for potential breeding places and spray insecticides for the fumigation of all buildings. This intensive campaign in 1940 had dramatic results. During the critical wet season the gambiae was pushed back on all sides, so that by the beginning of the dry season it had been practically restricted to the lower Jaguaribe Valley. This made possible the concentration in this area of a large number of workers for the final onslaught beginning in July. It can now be reported that no larvae or adults of gambiae have been found in the lower Jaguaribe Valley since the first week in September. A small additional focus lying some sixty kilometers beyond the known infested area was discovered in October, but it yielded readily to attack and was apparently clean by the middle of November. No evidence of gambiae in Brazil was found during the last 47 days of 1940.

Those directing the campaign no longer consider it rash to speak of the eradication of gambiae from Brazil, although it must be remembered that the struggle will not be won until the last fertilized female gambiae on this side of the Atlantic is destroyed. In any case, no matter how many isolated foci may yet be uncovered, the critical phase of this immediate campaign seems to be over. Certain mopping-up operations remain to be done as the search is continued for infested areas. The number and extent of these areas should become rapidly apparent with the onset of the rainy season early in 1941.—*The Rockefeller Foundation Report for 1940.*



BENJAMIN RUSH

THE FIRST MAN IN AMERICA TO BEAR THE TITLE PROFESSOR OF CHEMISTRY.

SCIENCE AT AMERICA'S FIRST UNIVERSITY

By CORNELL MARCH DOWLIN

ASSISTANT PROFESSOR OF ENGLISH, UNIVERSITY OF PENNSYLVANIA

THE campus of the University of Pennsylvania, on which was held a goodly portion of the sessions of the ninety-third annual meeting of the American Association for the Advancement of Science, is not notable for its spaciousness. And it seemed especially crowded during a week of September, 1940, when some 250 scholars, learned in the arts, the sciences, the humanities, came from all parts of the world, including embattled Europe, to address nearly 10,000 fellow guests, who were there to help celebrate the two-hundredth anniversary of the founding of the university.

Yet it is not a small campus. All told, the university property in West Philadelphia consists of 112 acres; but some 130 buildings have been erected on the grounds, and they elbow each other closely and adjacent private homes and commercial property. Besides, the buildings are not evenly distributed: included in the campus are eight playing fields, a huge stadium and two large gymnasiums —all devoted to the more or less scientific pursuit of athleticism—and the well-known Botanical Gardens, the most attractive portion of the grounds. Beyond the city limits, the university has more breathing space. In Chestnut Hill, on the northern boundaries of Philadelphia, is the Morris Arboretum, site of a Graduate School of Botany; to the west, along the West Chester Pike, is the Flower Observatory; farther west, at Valley Forge, are two farms, the site of a proposed experimental college of liberal arts; and northeast, near the Delaware River, are farms on which are carried on the activities of a School of Animal Pathology and important investigations (especially in embryology) of the Wistar Institute of Anatomy and Biology.

But into any corner of the present campus might be tucked the acre of ground and the single building at Fourth and Arch streets that served as the first home of the University of Pennsylvania. It was here, in 1740, that the pious people of Philadelphia, especially those interested in the less conservative aspects of religion, erected a large building for the meetings of the celebrated Wesleyan evangelist, George Whitefield, whose welcome in the established churches was not so warm as it had been on his arrival in Philadelphia in 1739. The building was the largest in the city, actually seventy feet by one hundred.[1] Funds to erect it were raised by means of a double-barreled appeal: the "chapel" would serve for religious meetings and also as a charity school. And it is because of the foundation of this school that the university has selected 1740 as the date of its own founding.

Although a board of trustees was organized and some endowment was collected, the charity school languished, and the next important educational step in Philadelphia was the publication in 1749 of Benjamin Franklin's pamphlet, "Proposals Relating to the Education of Youth in Pensilvania." This pamphlet was not a hasty effusion, for Franklin since 1743 had had definite ideas concerning education, and had discussed them with his associates. In their essence, his proposals for an academy were extremely practical. A variety of subjects, ranging from history, government and ethics to law, mercantile practices and even the mechanic arts was to be taught, prin-

[1] A picture of the first campus at about the year 1770 appeared in the December, 1940, issue of the SCIENTIFIC MONTHLY. The building with the belfry was the Whitefield meeting house; the other a dormitory erected in 1762.

THE OLD COLLEGE HALL OCCUPIED BY THE UNIVERSITY IN 1829 AND UNTIL THE UNIVERSITY WAS MOVED TO ITS PRESENT SITE IN 1872.

cipally in English. He did include the classics, but this, as he later pointed out, was to conciliate prominent citizens whose educational ideas were more conservative. The result was the formation of a board of trustees that took over the assets —and the liabilities—of the charity school, and at once started to select a faculty, which began instruction in 1751 in the remodeled chapel at Fourth and Arch streets. The institution was only an academy, however, and the trustees had more ambitious notions. Hardly had it begun to function fully before a new charter was granted, in 1755, incorporating "The Trustees of the College, Academy, and Charitable School of Philadelphia in the Province of Pennsylvania."

The next step in the organization of the Univeristy of Pennsylvania, at least as far as its name is concerned, was far from happy for the young institution. Under its first provost, the Reverend William Smith, the college became closely identified, first during the last years before the Revolution, with the Proprietary party, and then, during the Revolution, with the Tories[2] As a result, in 1779 the Assembly dissolved the old board of trustees and set up another, which was to administer the college under a new name, "The University of the State of Pennsylvania," a proper title because a medical school had been added in 1765. The new trustees, of course, were given possession of all the college property. The action was strongly tinged with politics, and similarly political was the act of the Assembly in 1789, when conservatives had regained power, to restore the old trustees to their property and privileges. The act of 1789 reestablished the college, but it did not extinguish the

[2] One result of the first provost's political activities was his imprisonment in the old jail at Third and Market streets in 1758 for an alleged libel on the provincial Assembly. From February to April of that year he conducted classes in the jail. For this and other details of the history and organization of the University of Pennsylvania, the reader is referred to "A History of the University of Pennsylvania," by E. P. Cheyney, University of Pennsylvania Press, 1940; and "The University of Pennsylvania Today," C. M. Dowlin, ed., University of Pennsylvania Press, 1940.

university; and although Philadelphia could hardly support one institution of higher education, the two continued to function concurrently, the college at Fourth and Arch streets, the ousted university in the building of the American Philosophical Society at Independence Square. But in 1791 reason prevailed, and under a new charter the two united to become the University of Pennsylvania.

The University of Pennsylvania, which thus became America's first educational institution to be called a university, continued at the Fourth and Arch streets location, with some outlying dependencies for the Medical School, until 1802, when, forced out by the encroachments of business establishments, it moved to Ninth and Chestnut streets. Its quarters here were the "Presidential Mansion," a handsome building erected for the use of the President of the United States in the 1790's, when it was expected that the Federal Government would remain permanently in Philadelphia. This building, purchased along with a number of adjoining lots, served as the home of the university until 1829, when it was razed and two buildings, College Hall and Medical Hall, both identical in external appearance and of a pleasing Georgian style, took its place.

By 1870 the Ninth Street location also had become unsatisfactory, and in 1872, following long negotiations with the city for the purchase of ground in West Philadelphia close to the west bank of the Schuylkill River, the College of Liberal Arts moved into a new College Hall. In 1874 the Medical School moved into a new Medical Hall just west of College Hall and also enjoyed the use of the University Hospital, which likewise was erected in 1874. These three buildings, along with a fourth, put up in 1878 to accommodate the Dental School founded in that year, formed the nucleus from which the present extensive plant of the University of Pennsylvania has grown.

But of greater general interest than such legalistic matters as corporate origins, organization and names, and the

COLLEGE HALL, THE FIRST BUILDING ON THE PRESENT CAMPUS

COMPLETED IN 1872. IN THE FOREGROUND IS THE BOYLE STATUE OF BENJAMIN FRANKLIN, WHICH ONCE STOOD BEFORE THE POST OFFICE AT NINTH AND CHESTNUT STREETS, SITE OF THE SECOND CAMPUS OF THE UNIVERSITY.

"PRESIDENTIAL MANSION," AT NINTH AND CHESTNUT STREETS
AND OTHER BUILDINGS OCCUPIED BY THE UNIVERSITY OF PENNSYLVANIA FROM 1806–1829.

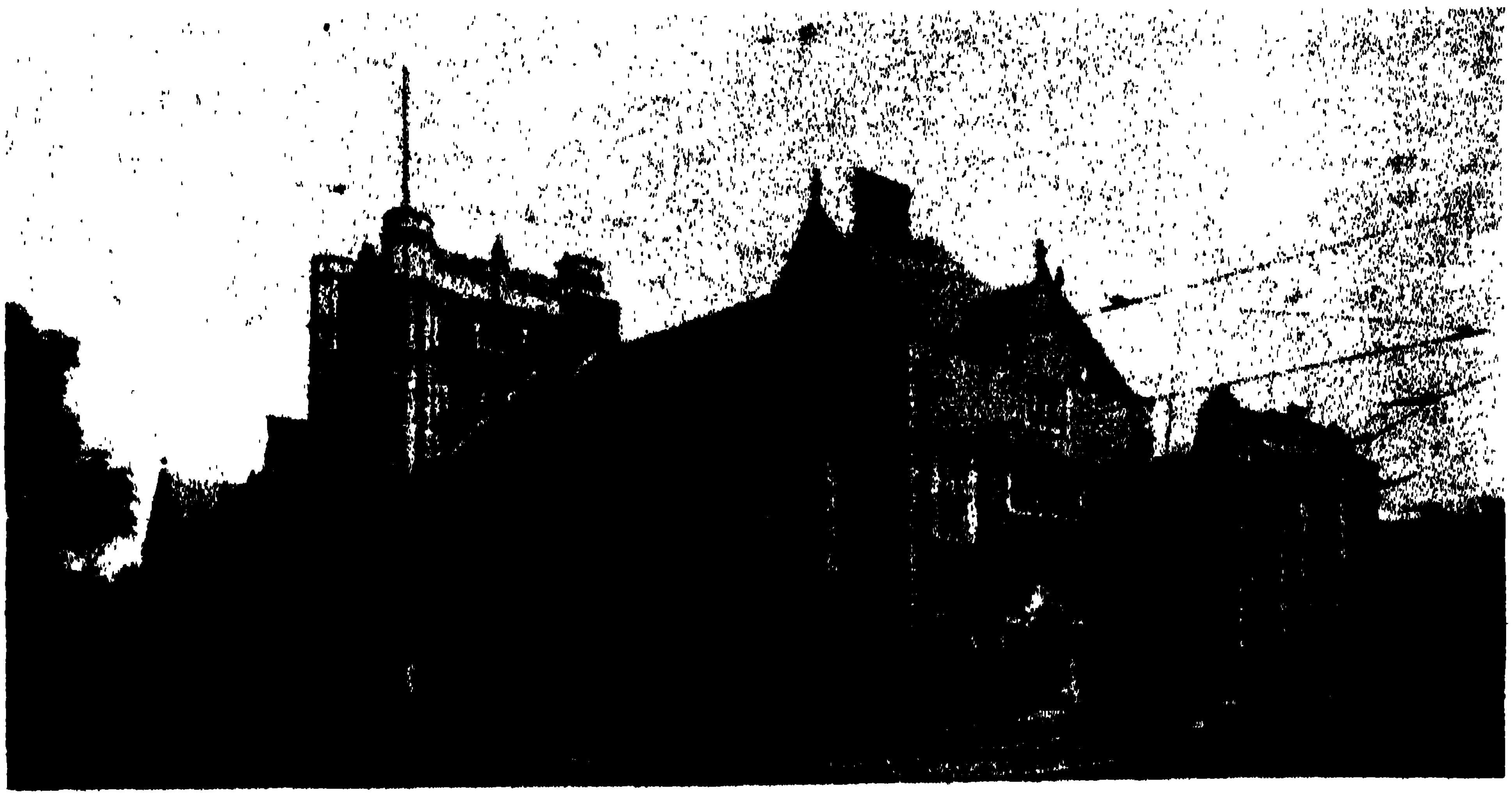
early, inadequate physical equipment, is the nature of the institution to which Benjamin Franklin in the middle of the eighteenth century lent his influence if not his name. It will be recalled that in 1748, the year before he began actively to promote the academy, Franklin had retired from business, intending to devote the rest of his life to scientific experiment. Closely associated with him in his investigations were Thomas Hopkinson and Philip Syng, both of whom were members of the original board of trustees set up in 1749. A third associate was Ebenezer Kinnersley, who in 1753 succeeded the first English master

"MEDICAL HALL" OCCUPIED BY UNIVERSITY MEDICAL SCHOOL, 1829–1874.
IT ACCOMMODATED AS MANY AS FIVE HUNDRED STUDENTS. "COLLEGE HALL" WHICH ADJOINED "MEDICAL HALL," HOUSED THE COLLEGE OF LIBERAL ARTS.

on the faculty, one David Dove, whose terrible temper figures large in the early annals of education in Philadelphia.

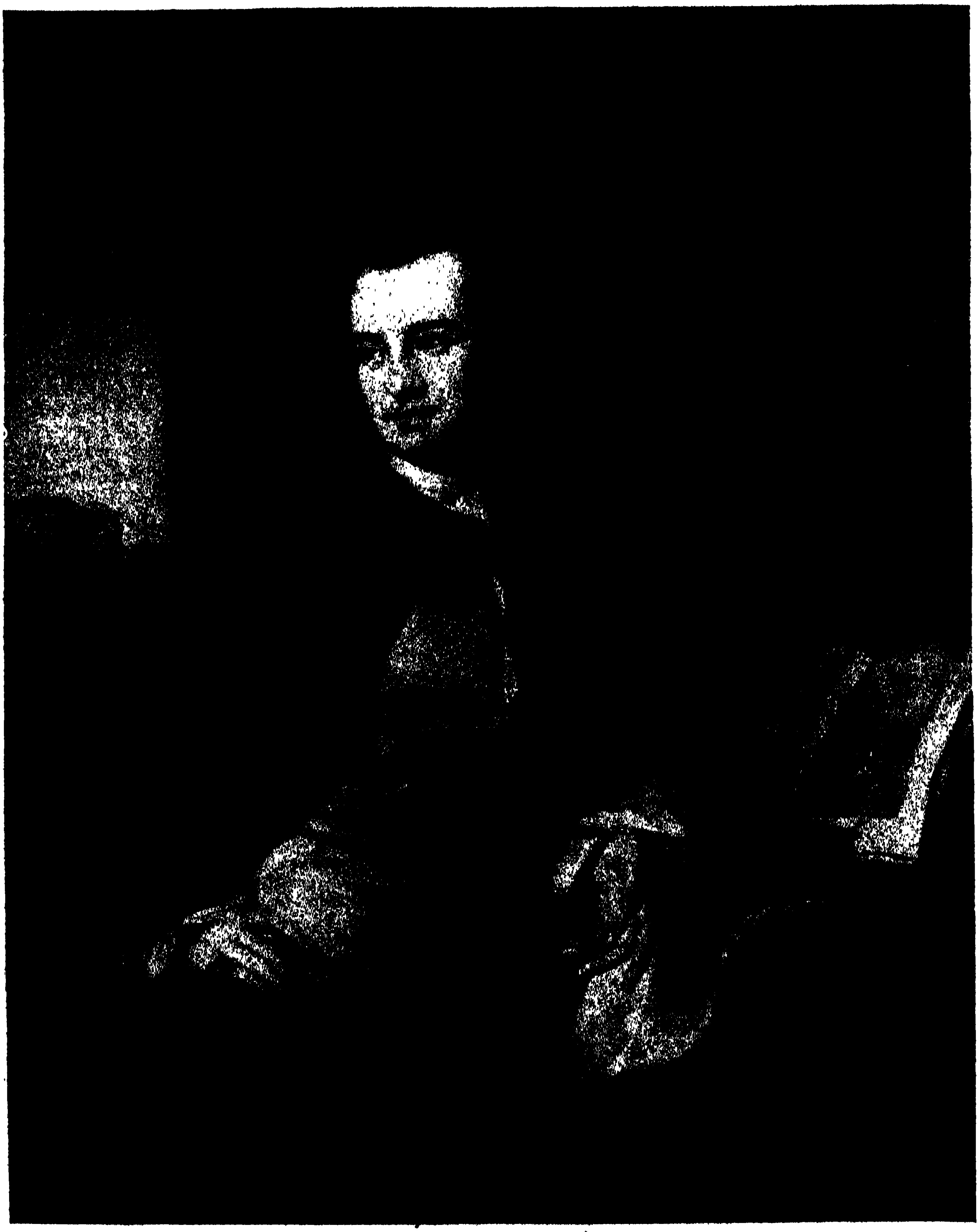
Another name to be mentioned especially in connection with the scientific atmosphere that prevailed from the beginning is that of Dr. William Smith, the stormy first provost. Appointed in 1754 after a long correspondence with Franklin, Dr. Smith became provost in 1755, when the college was established, succeeding the deceased Mr. David Martin, who as head of the academy bore the title of Rector. Provost Smith was engaged to teach logic, rhetoric and natural and moral philosophy, but natural philosophy was his especial interest. A capable mathematician and astronomer, he ably assisted David Rittenhouse during the observation of the transit of Venus in 1769, when the American astronomers placed the earth 20 per cent. farther from the sun by finding the horizontal parallax to be 8.6 seconds. And the second provost, the Reverend John Ewing, had similar talents, especially in engineering. He was very active in establishing state boundaries and in laying out highways. Still another name is that of David Rittenhouse, professor of astronomy and long a trustee, whose accomplishments as a mathematician, physicist and astronomer are too numerous to be recorded here.

Nor should it be thought that this interest in the physical sciences existed principally in the eighteenth century. During the earlier part of the last century a long list of distinguished men held the chair of natural philosophy. Among these were the two Robert Pattersons and John Fries Frazer, the latter a founder and the first president of the Academy of Natural Sciences, an organization intimately associated with the founding in 1848 of the American Association for the Advancement of Science. Worthy of especial mention is a grandson of Benjamin Franklin, Alexander Dallas Bache, an F.R.S. and a voluminous writer on scientific subjects. He was a president of the American Association for the Advancement of Science[8]



THE EVANS INSTITUTE AND SCHOOL OF DENTISTRY, FOUNDED IN 1878

[8] Other members of the faculty who have been president of the association are: George F. Barker, 1879; J. Peter Lesley, 1884; Daniel G. Brinton, 1894; Edward D. Cope, 1896; J. McKeen Cattell, 1924. The last named was appointed to the professorship of psychology at the University of Pennsylvania (the first chair in the world to bear that name) in 1888, but resigned in 1891 to accept the chair at Columbia.



JOHN MORGAN

PROFESSOR OF THE THEORY AND PRACTICE OF PHYSICK IN THE FIRST MEDICAL SCHOOL IN AMERICA. THE PICTURE IS A CONTEMPORARY PORTRAIT BY ANGELA KAUFMAN. IT HANGS IN THE LIBRARY OF THE SCHOOL OF MEDICINE OF THE UNIVERSITY OF PENNSYLVANIA.

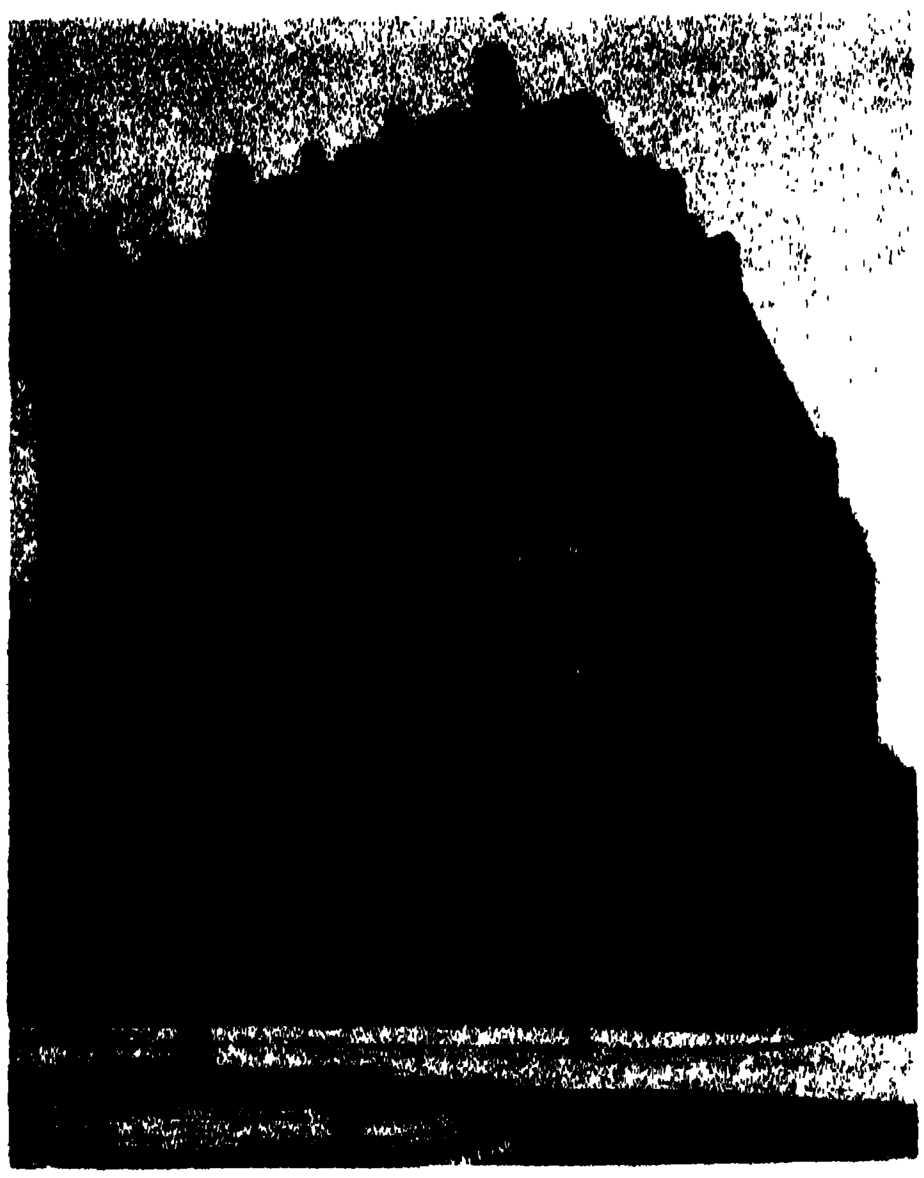
and of the National Academy of Sciences, and also was prominent in the work of the Smithsonian Institution, the United States Coastal Survey and the American Philosophical Society.

Although these men taught chemistry as well as physics, chemistry, during the first century of the university's history quite naturally is more particularly associated with holders of the professorship of chemistry, the first chair exclusively devoted to that science to be established in America. This chair was set up in 1769, and its first incumbent was Benjamin Rush, M.D., author of the first chemistry text-book published in America and a man famous especially for his work during the yellow fever epidemics in Philadelphia, but also for a variety of medical interests that would astonish a modern specialist. Although Rush was a member of the medical faculty, not all his successors were primarily interested in the medical aspects of chemistry. Notable among these was Robert Hare, inventor of the oxyhydrogen blowtorch and one of the first to build and operate an electric furnace.

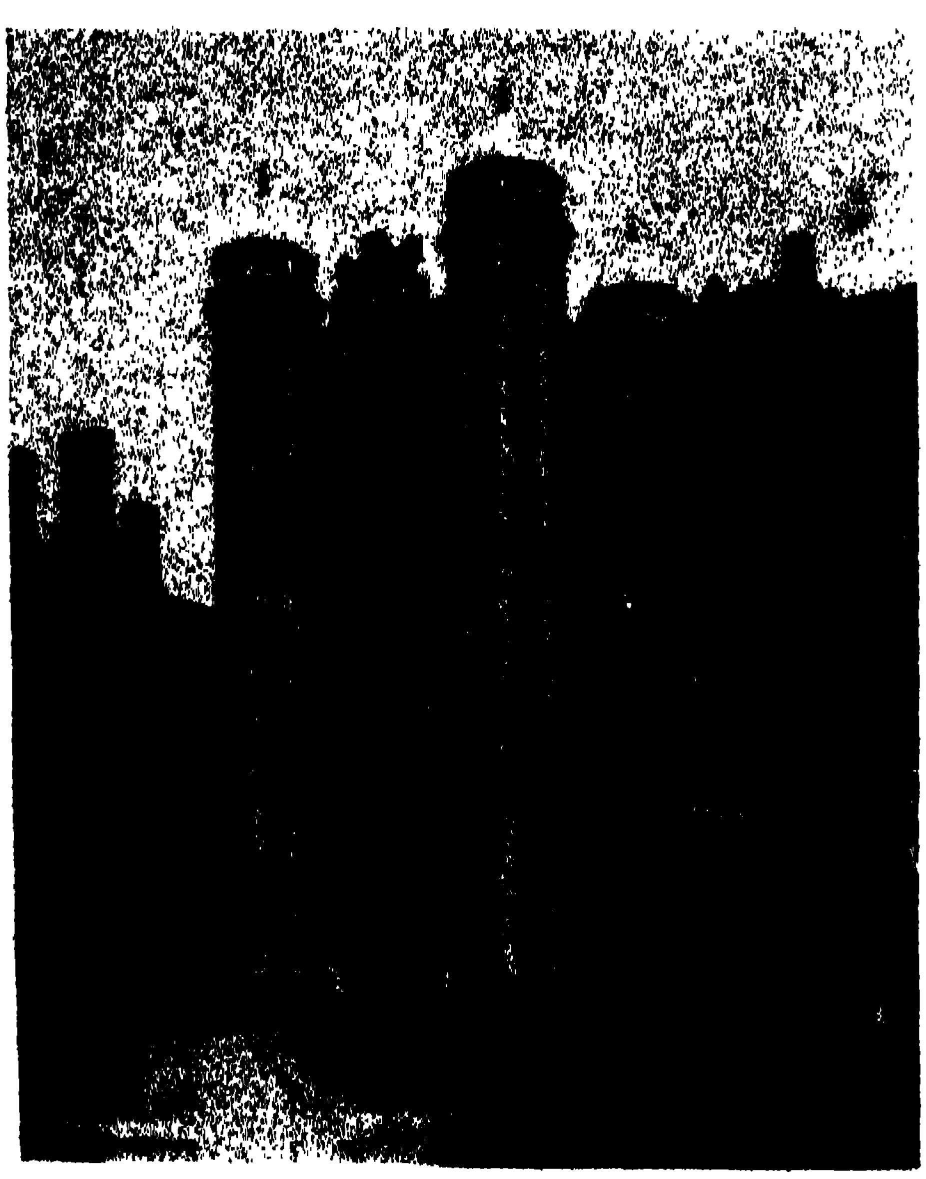
Mention of Benjamin Rush naturally suggests a statement, which must be all too short, concerning the first medical school to be established in America. In 1765, the trustees appointed Dr. John Morgan and Dr. William Shippen, Jr., as the first members of a faculty of medicine. Other appointments followed immediately, and the School of Medicine, of which this was the beginning, soon was attracting students from all English-speaking North America and even from Europe. Indeed, for nearly a century, the College of Liberal Arts remained essentially a local institution, largely because it was a strictly secular school (which may have contributed to the scientific atmosphere) without the support in students and funds that affiliation with a religious denomination would have provided. Its enrolment until the latter half of the last century rarely exceeded one hundred, while the medical students usually were four or five times that number. Space will not permit a recital of the accomplishments of the early School of Medicine, but mention should be made not only of Morgan, Shippen and Rush, but of Samuel P. Griffitts, founder of the United States Pharmacopœia; Caspar Wistar, author of America's first book on anatomy; and of Philip Syng Physick, "father of American surgery."

Until modern times, it must be admitted, the biological sciences as independent of medicine received somewhat scant attention. Although the university claims the distinction of having appointed, in 1789, the first professor of botany and natural history in the United States (Benjamin Smith Barton, pioneer investigator of American flora), botany and zoology as independent studies did not come into their own until 1884, when a School of Biology (now represented by the separate departments of botany and zoology) was founded. It is not the purpose of the present article to comment on the more recent history of the University of Pennsylvania, but three of the principal members of the biological faculty were men of such prominence that they demand attention. They were Joseph Leidy, Edward Drinker Cope and John A. Ryder, men whose work in comparative anatomy, American paleontology and embryology fills a prominent place in the records of the American Association for the Advancement of Science, or more particularly in those of the Academy of Natural Sciences.

It is also to be regretted that something can not be said of other modern developments such as the Towne Scientific School, the Moore School of Electrical Engineering, the Architectural School and the School of Fine Arts, the Wharton School of Finance and Commerce, the College of Liberal Arts for Women, the School of Education, the Graduate School, the Graduate School of Medicine, the Veterinary School, the University Press and the University Museum, the



THE MALONEY CLINIC
ONE OF THE LARGE HOSPITAL BUILDINGS OF THE UNIVERSITY. IT HOUSES A NUMBER OF THE DIVISIONS OF THE SCHOOL OF MEDICINE, INCLUDING THE JOHNSON FOUNDATION FOR RESEARCH IN MEDICAL PHYSICS.



THE "PROVOST'S TOWER"
ONE OF THE DORMITORY BUILDINGS.

latter being a division of the university known and active in the farthest reaches of the world. All the schools or departments just listed have been established since 1875, but in many cases their roots go back to far beyond that date. Another important school not mentioned heretofore is the Law School, the history of which begins in 1790, when the trustees established the first professorship of law in America.

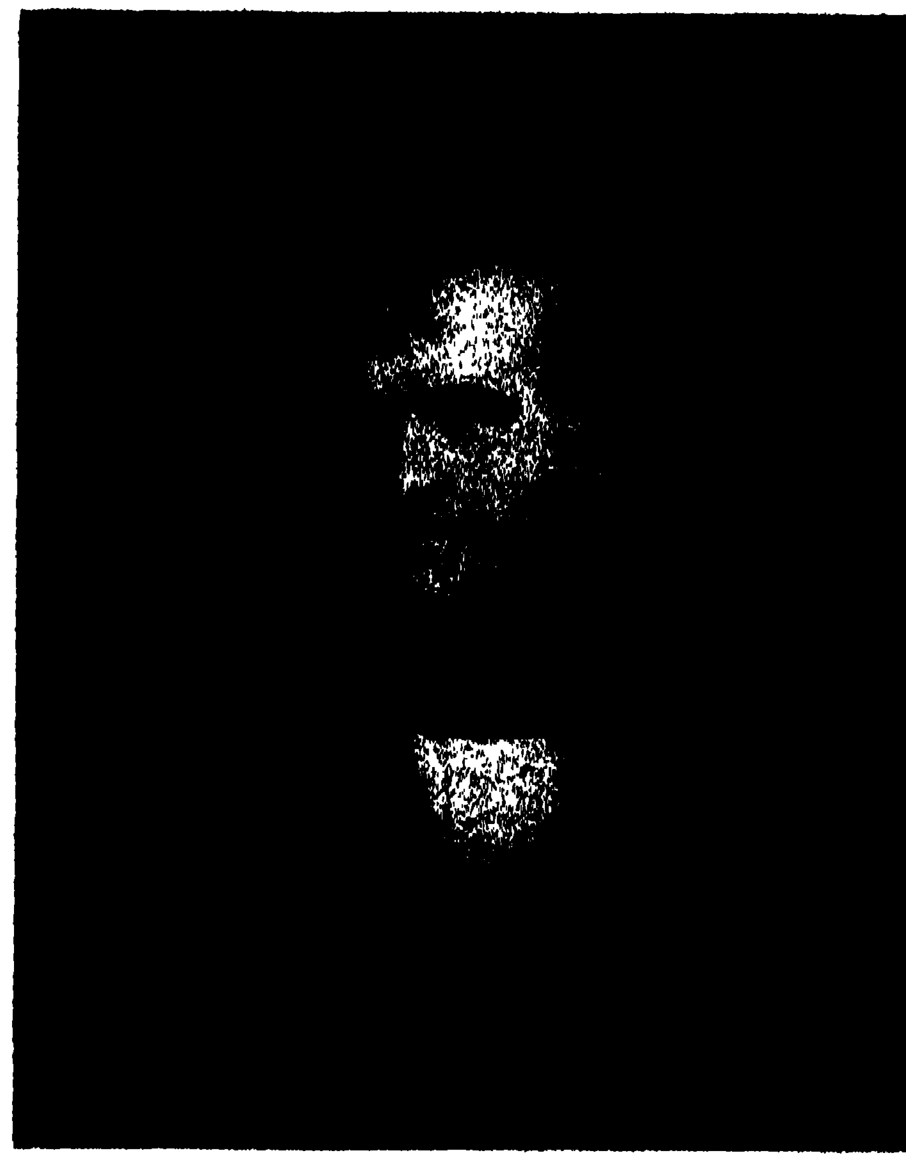
Slight though those roots may have been in the middle of the eighteenth century, when a handful of students was taught by less than a handful of professors, they have grown as the United States has grown, until to-day upwards of 17,000 students receive instruction in almost every branch of learning from a faculty of nearly 2,000 members.

The increase in faculty and students has been accompanied by the increase in physical equipment that already has been noted; but the increase in equipment has not been a change merely in quantity. If subjects and methods of instruction had remained the same during 200 years, classrooms and lecture-rooms similar to those of the old academy at Fourth and Arch streets, but more numerous, would serve to-day. Subjects and methods have changed, however. With the growth of the nation, contributing to that growth and also resulting from it, has come the increased attention paid to the sciences and changes in the equipment needed in education and research.

To cite one example, Theophilus Grew, the first professor of mathematics, doubtless employed few aids other than pencil and paper, protractor and dividers. At present the building of the Moore School of Electrical Engineering contains a sixty-ton apparatus known as a differential analyzer, a complex mechanism of motors, gears, cams and pantographs. Since it was erected in 1935, this machine

has been solving differential equations, providing in one hour a solution that otherwise might require a week of concentrated effort or perhaps could not be obtained at all.

Or to cite another example, in 1749 Benjamin Franklin rigged up two large Leyden jars with which he intended to kill his Christmas turkey, but which very nearly killed him.[4] The apparatus for experiments in natural philosophy in the old college was similar, though probably less powerful, consisting of Leyden jars, electrostatic generators and vacuum pumps. But to-day a part of the equipment of the Department of Physics is a Van de Graaf generator, or "atom smasher," which in effect is a Leyden jar and electrostatic generator capable of creating a charge up to five million volts; and a sixty-inch cyclotron which will develop much greater energy is about to be constructed for the Department of Radiology in the School of Medicine. Such a force, if properly directed, might well alter the course of history—and for the better, if American scientific workers have their way.

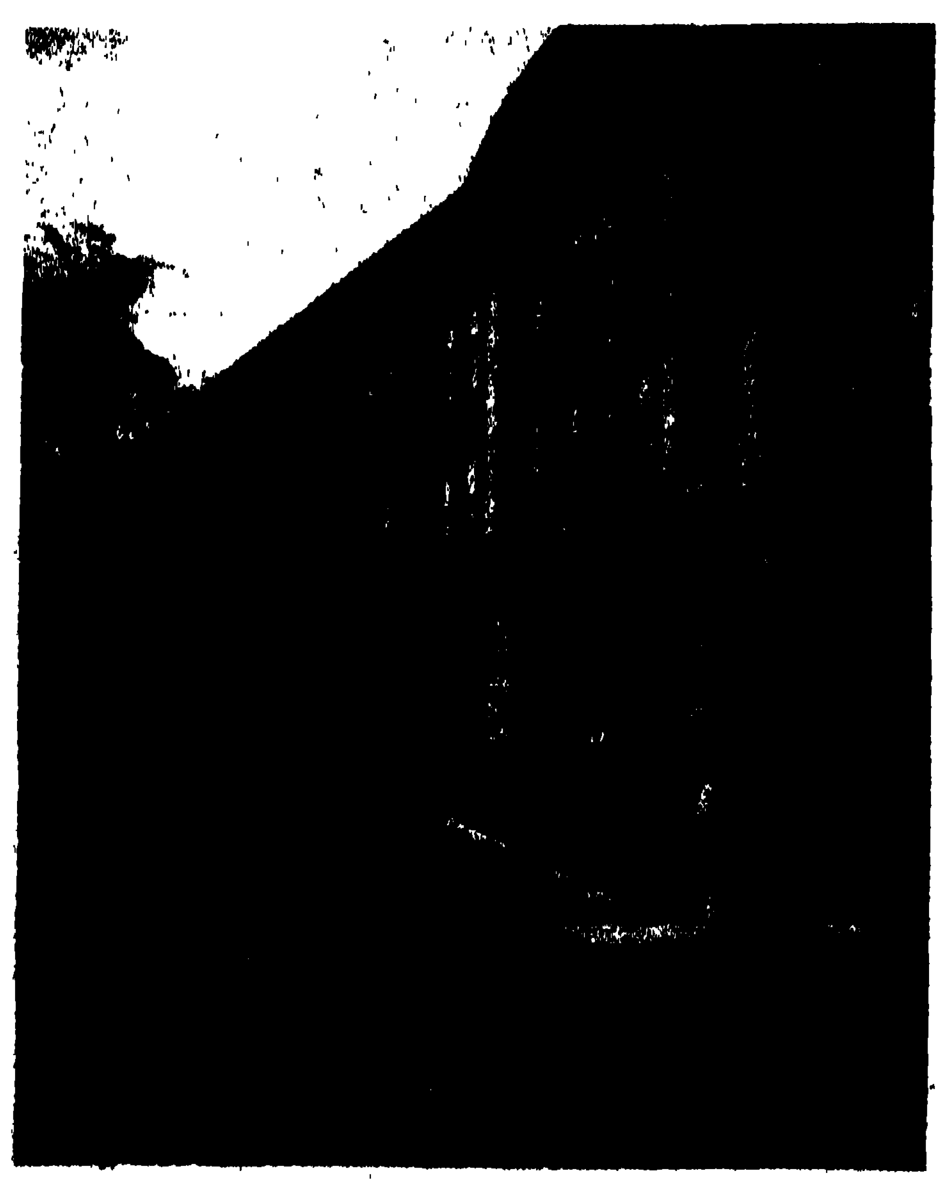


ROBERT HARE

PROFESSOR OF CHEMISTRY AT THE UNIVERSITY OF PENNSYLVANIA, WHO INVENTED THE OXYHYDROGEN BLOWTORCH.

Benjamin Franklin and the Social Sciences

To the average layman, the American Association for the Advancement of Science is an organization concerned with the physical sciences or possibly with the biological sciences as well. And yet the association has standing committees on history, education, the social and economic sciences and even (though not at present) on manufactures and commerce. Because of this interest in the social sciences and also because the matter has never been explored, it seems appropriate to outline here the influence of Benjamin Franklin on teaching and re-

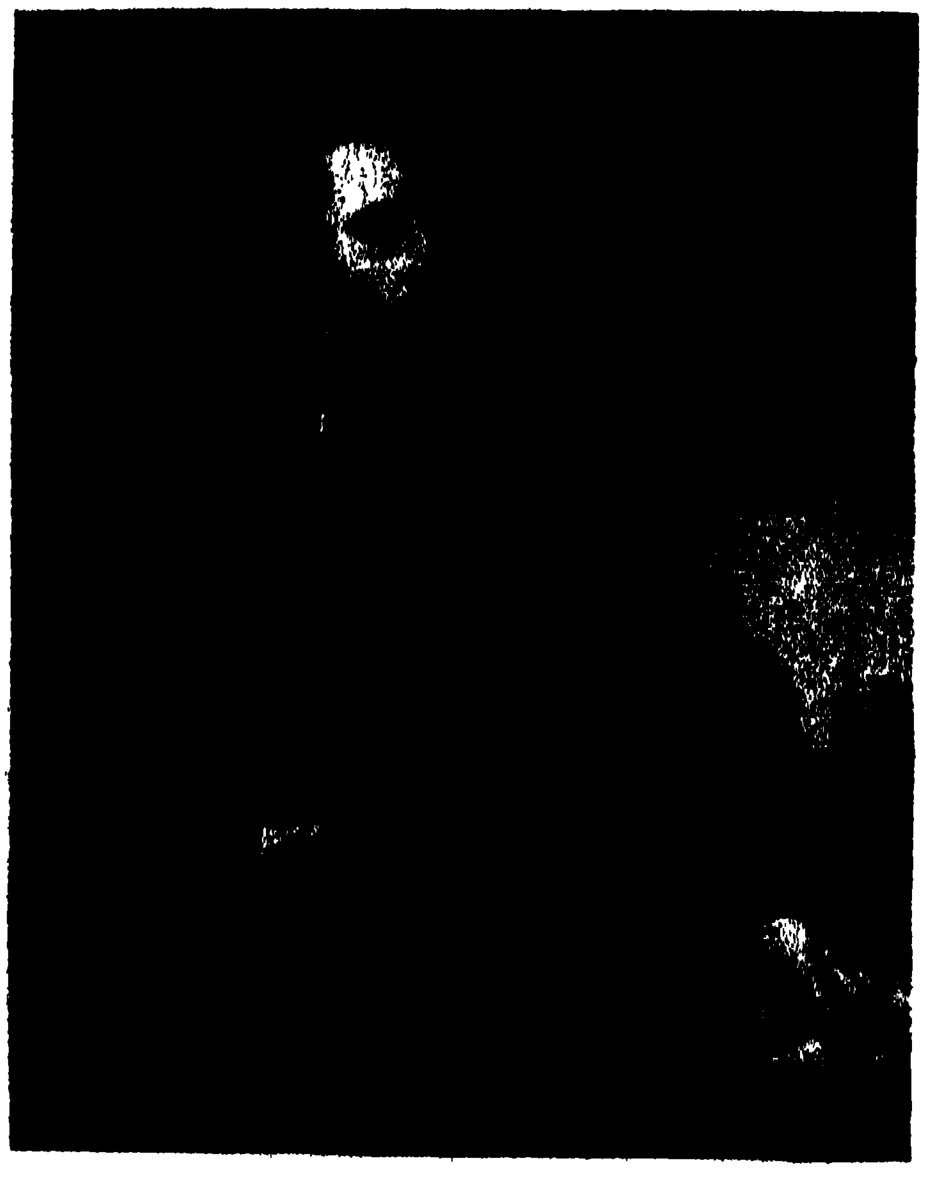


THE ENGINEERING BUILDING

FROM THE EAST. HOME OF THE TOWNE SCIENTIFIC SCHOOL, AND ERECTED IN 1904.

[4] Carl Van Doren, "Benjamin Franklin" (New York: The Viking Press, 1938), pp. 161–62.

JOSEPH WHARTON
FOUNDER OF THE WHARTON SCHOOL.



HENRY REED
WHO AS ASSISTANT PROFESSOR OF PHILOSOPHY AND LATER AS PROFESSOR OF ENGLISH LITERATURE TAUGHT NOT ONLY ENGLISH AND PHILOSOPHY BUT ALSO POLITICAL ECONOMY. HE WAS ONE OF THE FIRST TEACHERS OF THE SOCIAL SCIENCES IN AMERICA, BUT HE WAS BEST KNOWN FOR HIS LECTURES ON LITERATURE, BEING THE FRIEND OF WORDSWORTH AND THACKERAY.

search in the social sciences in the United States as that influence showed itself in the curriculum at the University of Pennsylvania. Oddly enough that influence revealed itself for approximately 130 years in the teaching of English.

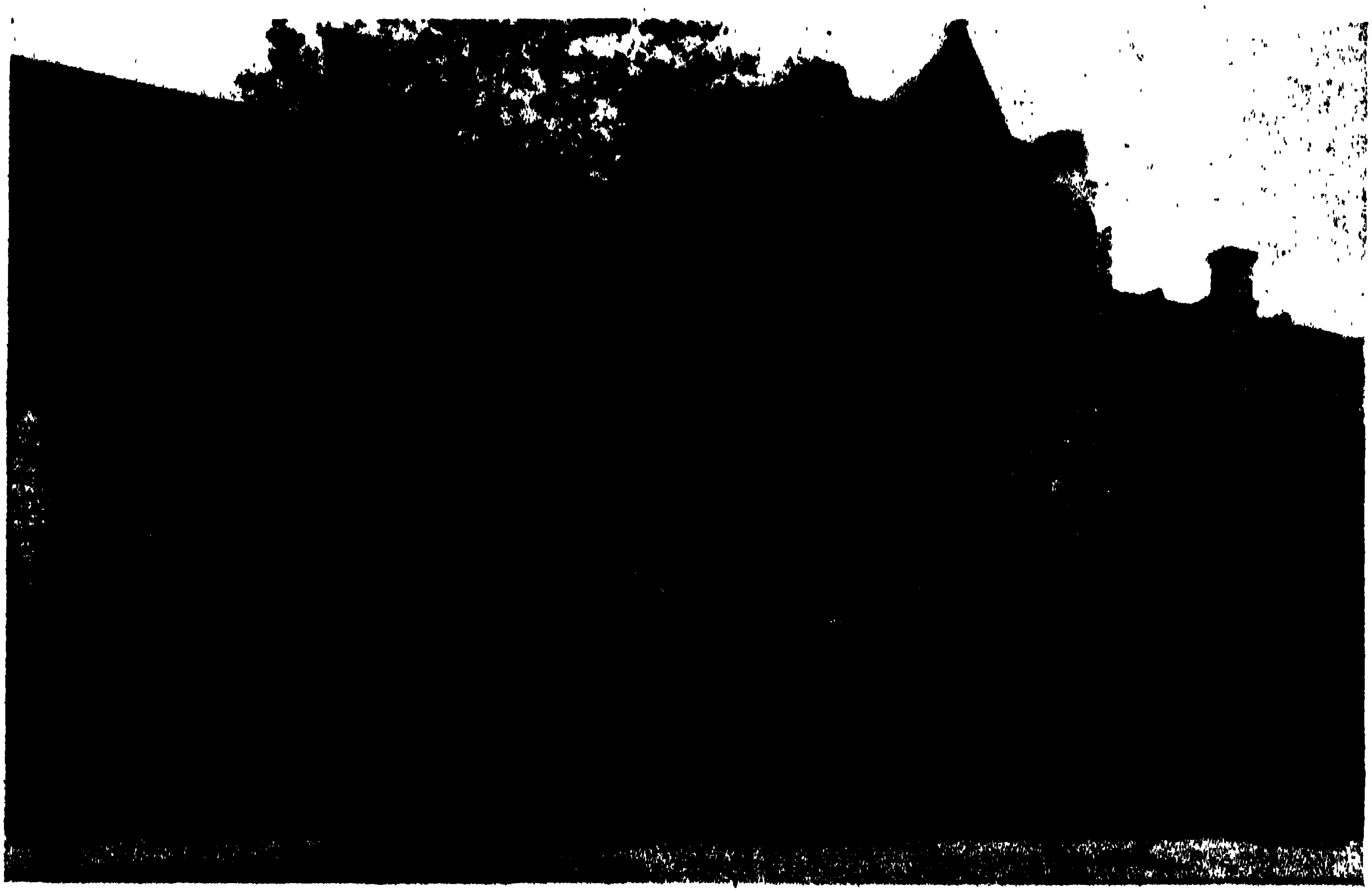
Franklin's "Proposals" of 1749 were largely concerned with the teaching of English as a tool useful in later life. The pamphlet makes it clear that the students' reading was not to be for the purpose of learning the beauties of literature but for cultivating a clear and concise style which, in either writing or speaking, would be serviceable to the good citizen. "To form their Stile," he says, "they should be put on Writing Letters to each other, making Abstracts of what they read; or writing the same Things in their own Words;" and in another place: "Indeed the general natural Tendency of Reading good History, must be, to fix in the Minds of Youth deep impressions of the Beauty and Usefulness of Virtue of all Kinds, Publick Spirit, Fortitude, &c." Furthermore, "*History* will show the wonderful Effects of Oratory, in governing, turning and leading great Bodies of Mankind," and "Modern Political Oratory being chiefly performed by the Pen and Press, its Advantages over the Antient in some respects are to be shown." Of especial significance, as will shortly appear, is the statement: "*Grotius*, *Puffendorff*, and some other Writers of the same Kind, may be used on these Occasions to decide their Disputes."

In fact Franklin considers that nearly the entire curriculum, through the teaching of English by means of reading, can be looked on as a part of the instruction in English, for he asks, "But if History be made a constant part of their Reading . . . may not almost all Kinds of useful Knowledge be that Way introduc'd to advantage, and with Pleasure to the Student?" Then follows a long list of useful subjects, beginning with geography and ending with "The His-

tory of *Commerce*, of the Invention of Arts, Rise of Manufactures, Progress of Trade, Change of Seats, with the Reasons, Causes, &c."

It might be argued, very reasonably, that Franklin himself did not associate "almost all kinds of useful knowledge" with the teaching of English; that he had merely passed with a hasty transition from the reading that would improve the style of English composition to the reading of history, political economy, international law and even geography. gentlemen taught is of interest to us here.

The courses given by the assistant professor of moral philosophy are as follows: to the Freshmen, "Cicero's Orations. English Grammar reviewed. Themes. Roman and Grecian Antiquities. English Composition. Declamation;" to the Sophomores, "History and Geography, ancient and modern. Rhetoric. Criticism. Elocution. English Composition. Declamation;" to the Juniors, "Logic. General Grammar.



LOGAN HALL, OCCUPIED BY THE WHARTON SCHOOL, FOUNDED 1881

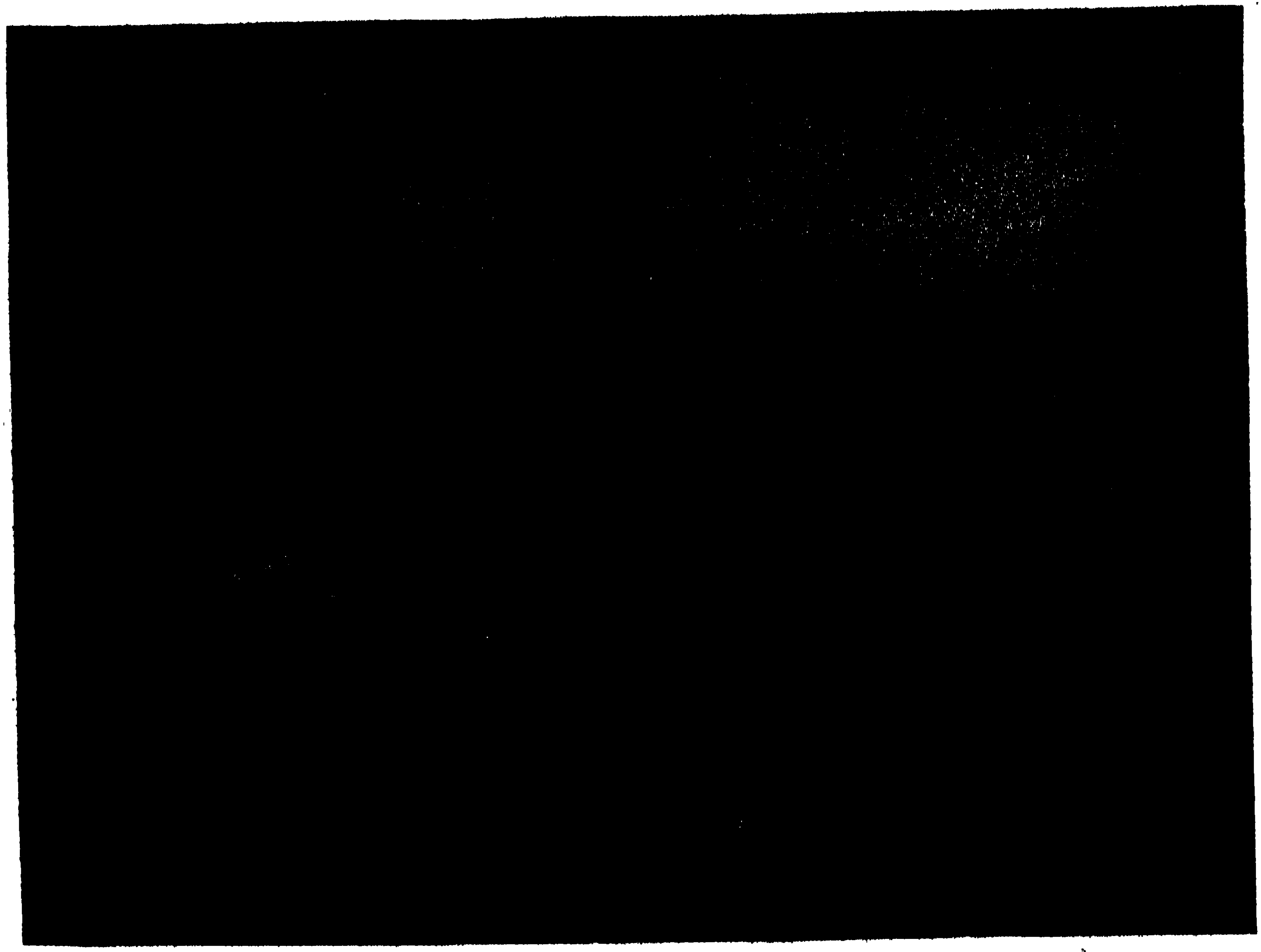
But let us turn to the university catalogues to see what they reveal concerning Franklin's views as actually put into effect. In the catalogue for the academic year 1828–29, the oldest in the University Library, we find the complete curriculum, arranged according to the professors who taught the courses. There is a professor of mathematics, of languages, of natural philosophy, a professor of moral philosophy (the provost), and an assistant professor of moral philosophy. What the latter two

Moral Philosophy. English Composition. Forensic discussion." In the Senior year the provost took over and taught: "Evidences of Natural and Revealed Religion. Metaphysics. Natural and Political Law. Elocution. Composition. Forensic discussions."[5]

By itself this strange medley does not

[5] The catalogue assigns the Junior course to the professor of moral philosophy and the Senior course to the provost, who were the same person. Undoubtedly the assistant professor was in charge during the Junior year, as is stated in succeeding catalogues.

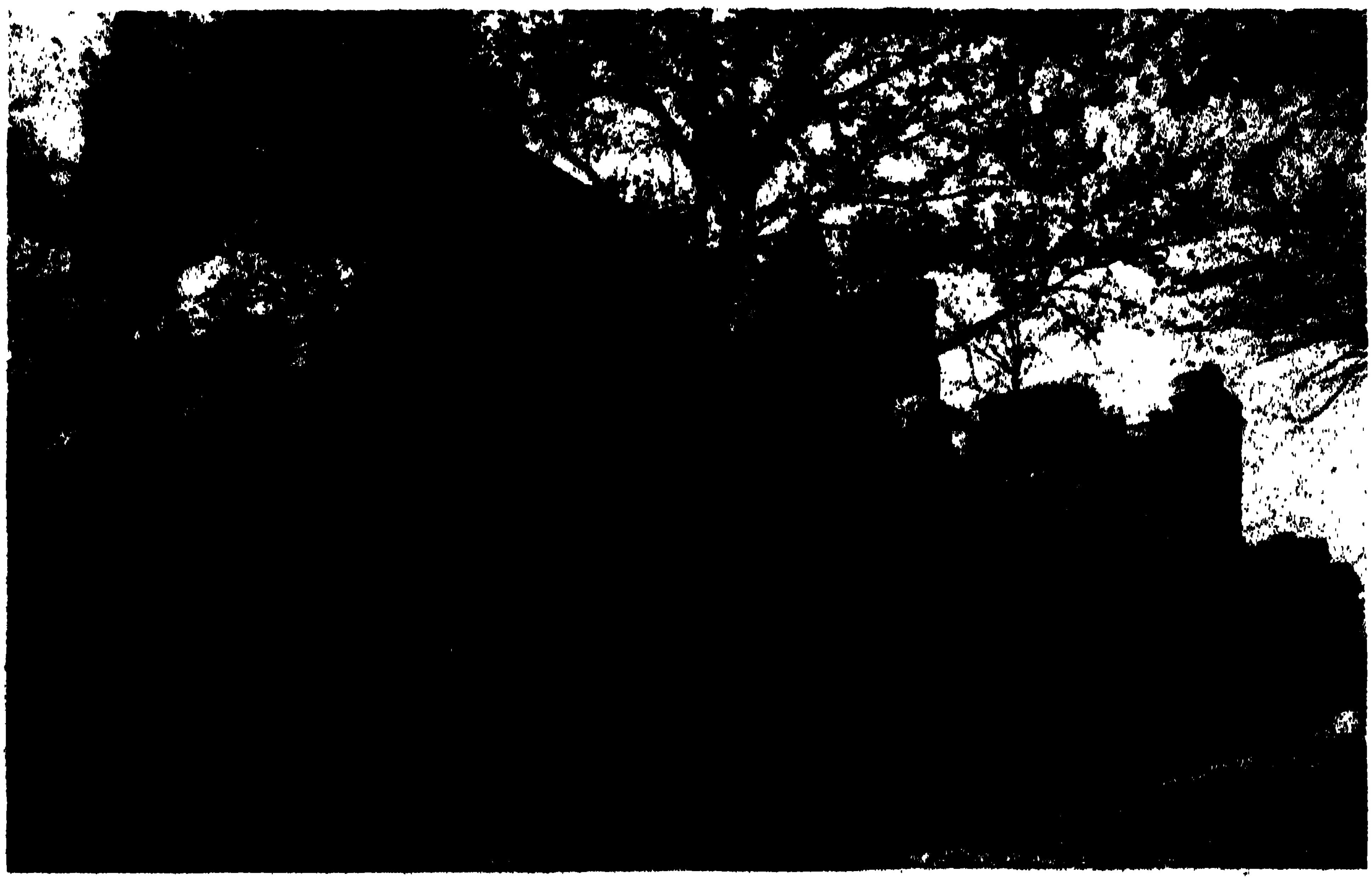
HOUSTON HALL, THE FIRST "STUDENT UNION" BUILDING IN AMERICA



THE FORECOURT OF THE UNIVERSITY MUSEUM COMPLETED IN 1899
FIRST UNIT OF THE EXTENSIVE PLANT HOUSING THE COLLECTIONS IN ARCHEOLOGY AND ETHNOLOGY.

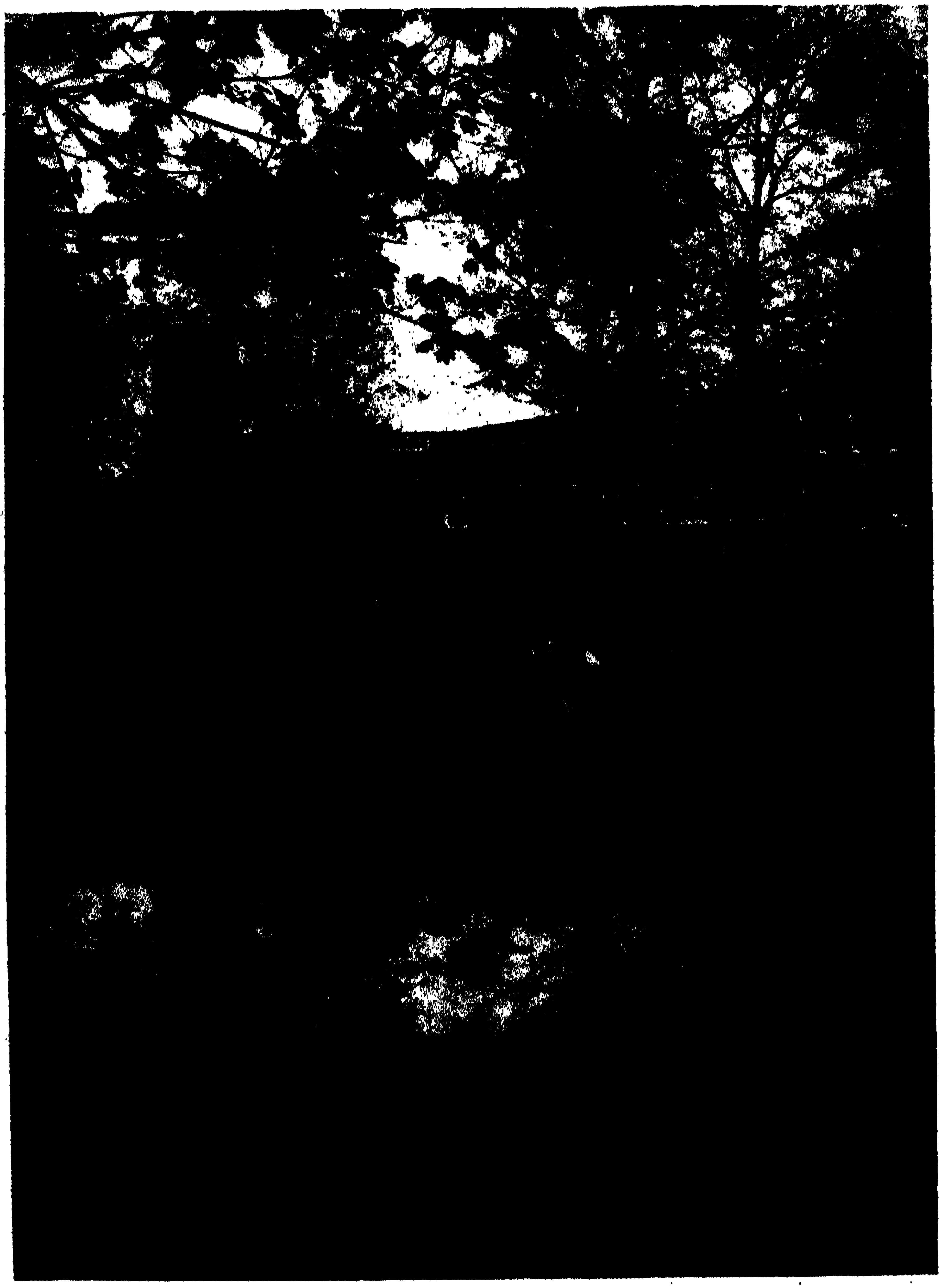
indicate that English courses were the vehicle for instruction in subjects ranging from geography to history and political science; rather, perhaps, that a small student body and a small faculty obliged the philosophy professors to teach everything that did not fall to the professors of languages, mathematics, or natural philosophy.

But if we turn to the catalogue for 1832–33, we find that a change has taken place. The courses, if they can be called that, are essentially the same. However, instead of being listed by professors, they are labeled *Mathematics*, *Classics*, *English*, etc., and the interesting point to observe is that the courses assigned in the earlier catalogue to the professor and assistant professor of moral philosophy are now classified as *English;* for instance, the provost's course for Seniors appears as: "English. Evidences of Natural and Revealed Religion. Intellectual Philosophy. Law of Nations and Political Law, (Kent's Commentaries.) English composition. Forensic discussions." It is interesting to observe also that the entrance requirements in English consisted of "The elements of English grammar and of modern geography." And it is likewise worth noting that the assistant professor of moral philosophy, now the famous Henry Reed, is stated to have charge of the Department of English Literature, but the curriculum gives no hint of instruction in English literature save that "Readings in Prose and Poetry" has been added to the "English" course given to Freshmen. Certainly it would seem that the university authorities in the 1830's were aware of Franklin's linking, through reading, of the teaching of English and of such subjects as geography and international law, but whether it was the result of tradition or a return to Franklin's "Proposals" it is impossible to say here.



A CORNER OF THE DORMITORIES OF THE UNIVERSITY OF PENNSYLVANIA

The question may next arise, how long did this association of the teaching of history, political science and similar subjects with English continue. Before an-



A PORTION OF THE BOTANICAL GARDENS OF THE UNIVERSITY
THE BUILDING TO THE REAR IS THE ANATOMY WING OF THE MEDICAL LABORATORIES.

swering it, we will jump to the catalogue of 1873–74, in which, as for many years, English grammar and geography constituted the entrance requirements in English; and although the curriculum, after the passage of some thirty years, has evolved slightly, it is still clearly recognizable as the same. These are the "English" courses:

Freshman Class

English.—*Freeman's Outlines of History* and Lectures, with *Labberton's* Historical Atlas. Compositions and Declamations.

Sophomore Class

English.—Elements of Rhetoric. *Bains Rhetoric*, with Lectures and Practical Exercises. Earle's *Philology of the English Tongue*, with Lectures. Composition and Declamations.

Junior Class

English (Required).—Compositions and Declamations. Logic. (*Atwater*.)

English (*Elective* with *Pure Mathematics*).—Roman History (*Student's Gibbon*). Historical Lectures.

Senior Class

English (Required).—*Guizot's* History of Civilization. *Taine's* English Literature. International Law (Lectures). Social Science (*Carey* and Lectures). Compositions and Original Declamations.

English (*Elective* with *Pure Mathematics*).—Lectures on Modern History. Lectures on the Relations of English History to English Literature.

The catalogue does not directly indicate who conducted these courses, but we can assume that the work was divided between Provost Charles J. Stillé, professor of history and English literature; John G. R. McElroy, adjunct professor of Greek and history (who had once held the title of assistant professor of rhetoric and history); and Samuel M. Cleveland, professor of rhetoric and oratory.

The catalogue for 1873–74 was selected here because the Senior required course in English for that year included "Social Science (*Carey*),"[6] and because in the following year social science was dignified with the appointment of a professor of social science. This was the Reverend Robert Ellis Thompson, who since 1868 had served either as instructor or assistant professor of mathematics. But even though there was a professor of social science in 1874–75, the courses in English remained the same as in the preceding year, except that Carey's book was omitted from the required Senior course.[7]

But by the year 1880–81 a classification of courses more in accordance with our modern conception of a curriculum appears in the catalogue. Here English is clearly indicated as the study of composition, literature and philology; and history and social science are separate, each under its own label. The latter, which is given only to Seniors, appears as follows: "Social Science (Required).—International Law (Lectures). Thompson's *Social Science and National Economy*." In almost every respect the subjects and the text-books in this curriculum are the same as before; they have merely been given new labels, and it is obvious that the new course in social science is the old required Senior English course under a new name.

The year 1881 is important for the University of Pennsylvania, and especially for the social sciences as taught there. In March of that year, Joseph Wharton, a prominent Philadelphia business man, submitted to the trustees an elaborate plan for the establishment of a "School of Finance and Economy" which he proposed to endow. In purpose, the school bore an astonishing similarity to the academy projected in Franklin's "Proposals" of 1749. The

[6] H. C. Carey, "Principles of Social Science," 3 vols., 1858–59.

[7] It is possible that Professor Thompson, while still assistant professor of mathematics, had given all or a part of the Senior course, instead of one of the other three men. In any case, however, it is obvious that the inclusion of "social science," whether Thompson or another professor introduced it, was in keeping with the practice that originates ultimately in Franklin's "Proposals."

HAMILTON WALK GATEWAY SHOWING THE ZOOLOGY BUILDING

students, well trained in English and certain other cultural subjects, would learn, through the study of history, political economy, law and mercantile practices, to become useful members of the community, both as honest and competent business men and as public servants. Of course the offer was accepted, and as a result the first university school devoted to the social sciences, in both their

THE HOME OF THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY AND ITS FAMOUS RAT COLONIES. IT WAS FOUNDED IN 1892.

theoretical and practical aspects, was founded.

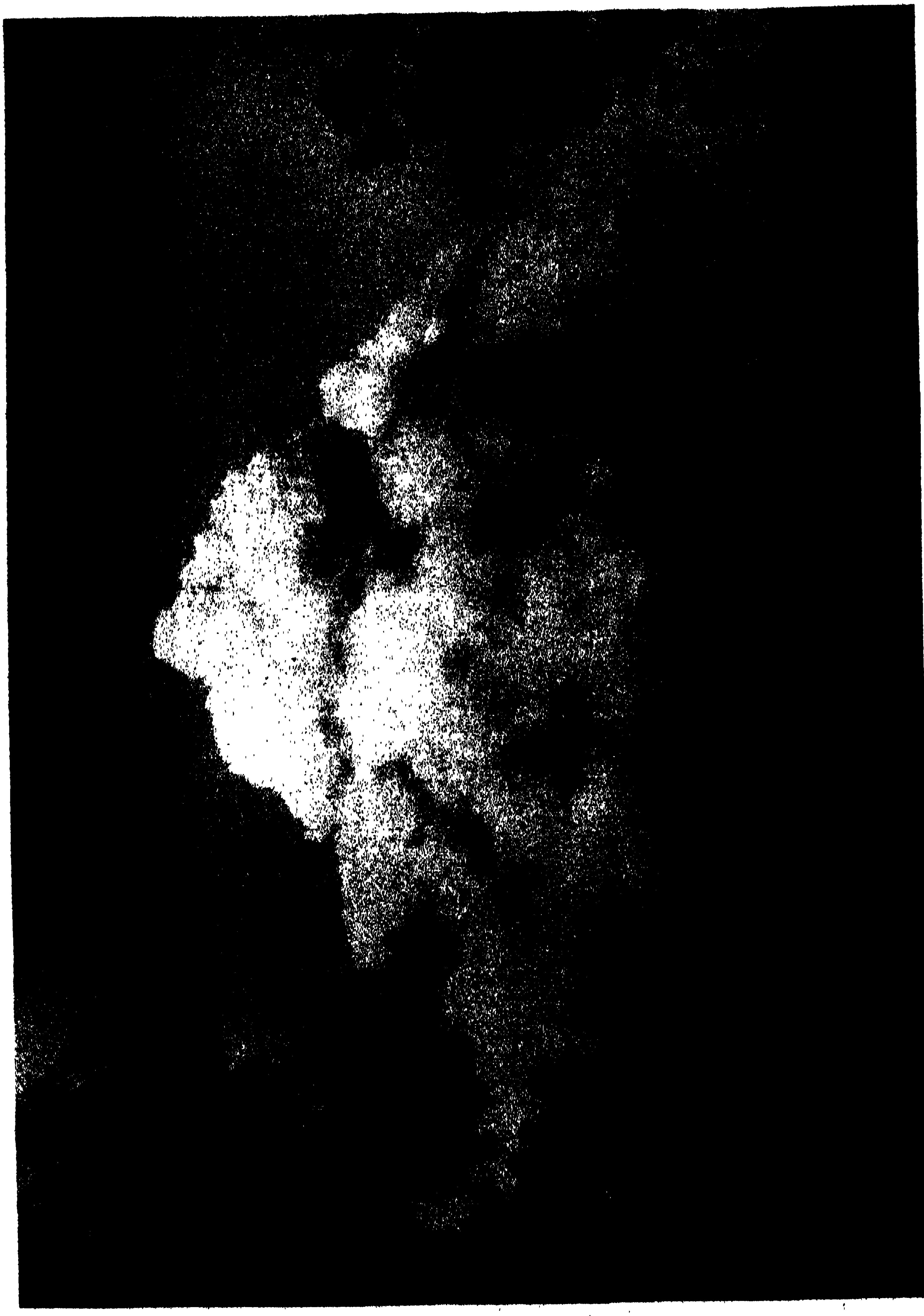
No radical change, however, in the instruction already given in the university followed. Professor Thompson continued to be professor of social science, giving the same course to Seniors in the College of Liberal Arts. But in the Wharton School announcement for 1881–82, this course broadens out into a series of courses, given only in the Junior and Senior years, on "History and Functions of Money"; "Municipal, State, and National Taxation"; "Industry, Commerce, and Transportation"; "Wage Questions. The Relations of Capital and Labor"; and "Lectures on Living Issues," such as Socialism, Communism, and free trade and protection—all of them matters, we may be sure, that Professor Thompson had treated in the original course in social science.

Professor Thompson continued to be the principal teacher in the Wharton School (his only colleague was an instructor in accounting) for but two years. For reasons that we can not explore here, he retired from the faculty of the school and accepted the appointment to the now vacant chair of history and English literature once occupied by Provost Stillé, and his work was taken over by two new appointees, Edmund J. James, professor of finance and administration, and Albert S. Bolles, professor of mercantile law and practice.[8]

Naturally, changes appear in the Wharton School announcement for the following year, 1883–84. The term *social science* is dropped and new, more precise names are given to the courses: "Political Economy," "Political Science," "History of Trade, Manufactures and Commerce," etc. However, a number of the text-books remain the same, including one by Thompson, and it is evident that the new professors built on the older foundations. It is also evident that these foundations, on which has since been erected an important school devoted to the social sciences, reach as deep as to Franklin's "Proposals."

It has often been pointed out that in his later life Franklin showed some bitterness because of the manner in which the early trustees of what is now the University of Pennsylvania ignored his proposals for the teaching of practical subjects by means of English, and made the classics a too prominent part of the curriculum. As far as actual hours of instruction are concerned, his hostility, perhaps, was justified, but it is clear, nevertheless, that his ideas possessed remarkable vitality. That they continued to be put into practice long after his death and even until to-day is revealed by what seem to us the strange combinations appearing in the university catalogues of the last century.

[8] It is significant that a third appointment to the Wharton School faculty in 1883 was that of John Bach McMaster, the historian, to a new chair of American history. The first volume of his "History of the People of the United States," appeared in that year. Something of the importance of Edmund J. James with respect to the social sciences in America is indicated by the following: "James, Edmund Janes, 1855–1925, American economist and educator (Ph.D., Univ. of Halle), was professor of public finance and administration at the Wharton School of Finance and Economy [now Finance and Commerce] Univ. of Pennsylvania, 1883–96, and a leader of the so-called Pennsylvania school of economists. He was a founder of the American Economic Association (1885) and of the American Academy of Political and Social Science (1890), becoming the first president of the latter organization."—*Columbia Encyclopedia*, New York: 1935. The Economic Association is now affiliated with the American Association for the Advancement of Science. Professor Bolles wrote extensively on the history of American industry and finance.



A HEAVY SMOKE CLOUD FROM A LARGE FIRE[1]

PROGRESS IN FOREST FIRE CONTROL

By GEORGE M. GOWEN

CHIEF OF FIRE CONTROL, REGION 5, U. S. FOREST SERVICE

THE drier the fuel and the better the draft the easier a fire may start, the hotter it burns and the more difficult it is to extinguish. In these respects forest fires are comparable to fires built in a fireplace or stove.

Dryness of forest fuels depends on their moisture content. In turn moisture content depends on the amount and distribution of precipitation, the current relative humidity, evaporation rate and insolation.[1]

Local analyses of weather records, particularly in the West, where a large portion of the national forest area lies, indicate that precipitation in the forested areas has not only varied from year to year but also has exhibited distinct wet and dry periods or cycles. It appears that we are now in the driest of these dry cycles and that the general trend of precipitation is still downward. In addition to a general decrease in the annual precipitation, there seems to be a growing tendency for the distribution of the rain which does fall to be less general in extent as compared with past years. The records also indicate a general rise in temperature, slight, perhaps, but enough to influence fire danger to some extent.

Since precipitation is the basic source of the water content of forest fuels, it seems reasonable to expect that deficiencies in precipitation will result in drier forest fuels and consequently greater seasonal fire danger. The probability of forest fires covering larger areas and causing greater losses, of course, increases as the fire danger or severity of fire weather increases.

Despite fire weather conditions increasingly adverse to protection of the forests from fires, the area burned in the 200 million acres within national forests of the United States has been reduced consistently decade by decade. Using as an index the area burned over per million acres protected, the figures given in Table 1 illustrate this progressive reduction by 5-year periods.

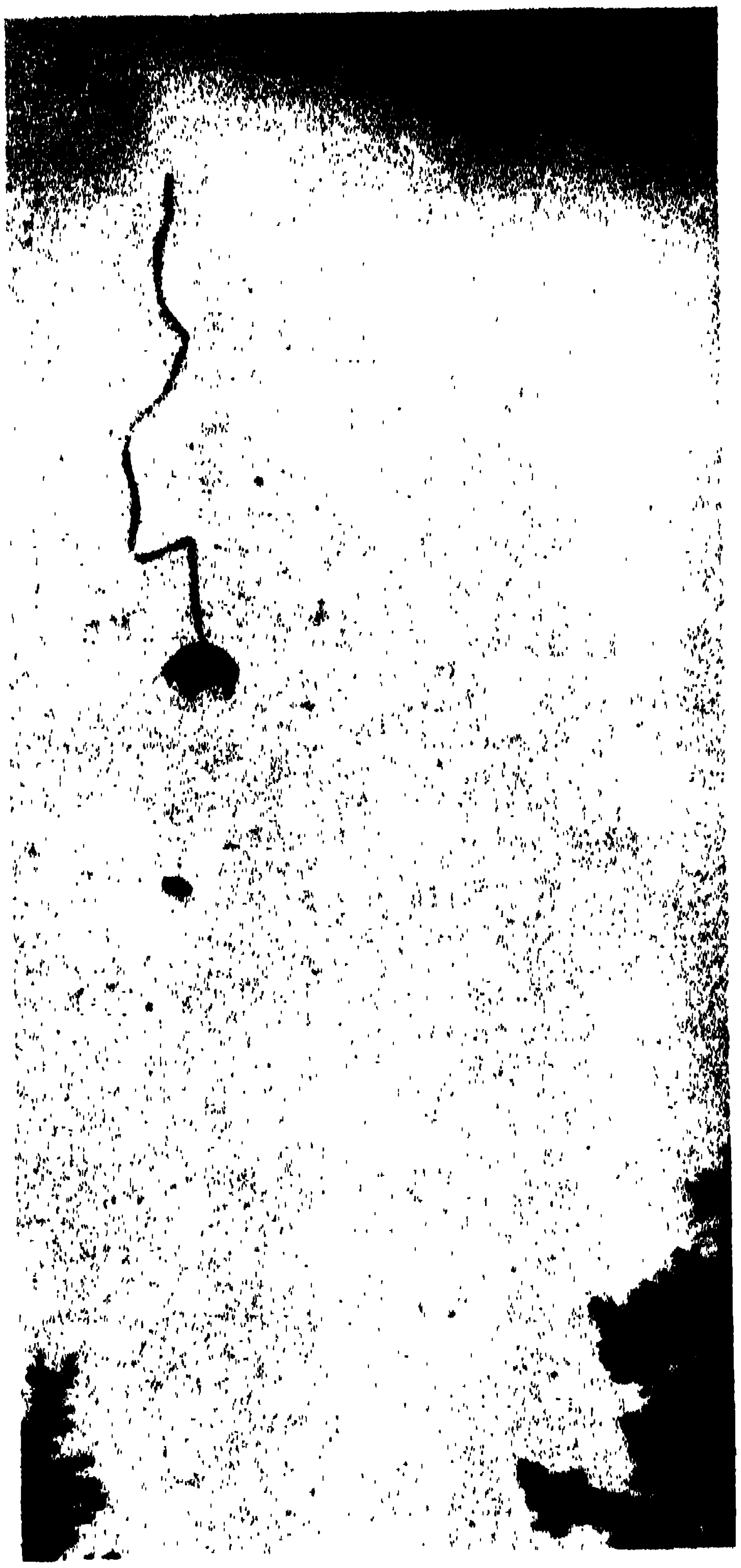
TABLE 1

5-year period	Average annual acres burned
1910–1914	8,400
1915–1919	6,300
1920–1924	3,100
1925–1929	3,600
1930–1934	2,400
1935–1939	1,480
1940 only	1,525

A single year of the 1940–1944 period is not sufficient to identify the continued success or a failure of fire-control efforts. However, in 1940 the more unfavorable fire weather, abnormal number of fires and concentration of large numbers of lightning fires in certain areas combined to produce a situation in which large losses might ordinarily have been expected.

During one 13-day period in 1940, July 11 to 23, the Northern Rocky Mountain Region was showered with over 1,700 lightning fires. This was twice the number ever previously experienced in any area and three times the total previously recorded in the 28,000,000 acres of the Northern Rocky Mountain Region, in so short a period. The gigantic task of assembling men to handle such a large

[1] A discussion of the interrelationship of the several phases of forest fire control appeared in THE SCIENTIFIC MONTHLY for July, 1939, pp. 21–30, "Forest Pyrology," by H. T. Gisborne, senior silviculturist of the Forest Service.



DELIVERY OF SUPPLIES[1]

FIRE FIGHTING SUPPLIES ON SIMPLE BURLAP PARACHUTE. THE STREAMER ALLOWS GROUND FORCES TO LOCATE THE LOAD READILY WHEN IT DROPS IN HEAVY COVER.

suppression job, transporting them to the fires and supplying them with tools, equipment and subsistence, although seemingly impossible, was done. The 1,700 fires were controlled with a loss of but slightly over 7,000 acres.

Except for the steady advance that has occurred in the various fields of fire control, the 1940 story might have been quite different. Losses might have increased substantially. Instead, the record shows approximately no increase over the previous 5-year average. Increased effectiveness in preventing fires from starting, in putting them out while still small, and in promptly controlling those which escape the initial attacking forces, have resulted from continuing efforts, through the years, to improve techniques and devise new methods of meeting the fire problem.

The old saying "An ounce of prevention is worth a pound of cure" applies doubly in the case of man-caused forest fires. Almost 50 per cent. of the 17,000 fires occurring annually within the national forests are of this class. Closer and closer analyses of the causes of individual fires and the underlying reasons behind them have, in many cases, permitted remedial measures to be devised and applied. Such measures have not resulted in a reduction of the total number of man-caused fires, but they have been effective in materially reducing the ratio between numbers of fires and the constantly increasing number of forest users and visitors.

The total number of fires is much too large and presents far too great a threat of loss. To reduce this total to a minimum and hold it down, is the goal of fire prevention. Education in what constitutes carelessness with fire and how to be careful has been an important part of fire prevention work. It is a continuing job, because of new users and the new generations who will become future forest users.

Positive measures—such as clearing railroad, highway and power line rights of way, use of spark arresters on automotive and steam equipment, providing prepared camps for the camping public, and regulation of the time and place for burning debris—have had their effect in holding the number of fire starts far below that which would have occurred if sustained efforts in this direction had not been made. Incendiary fires, those wil-

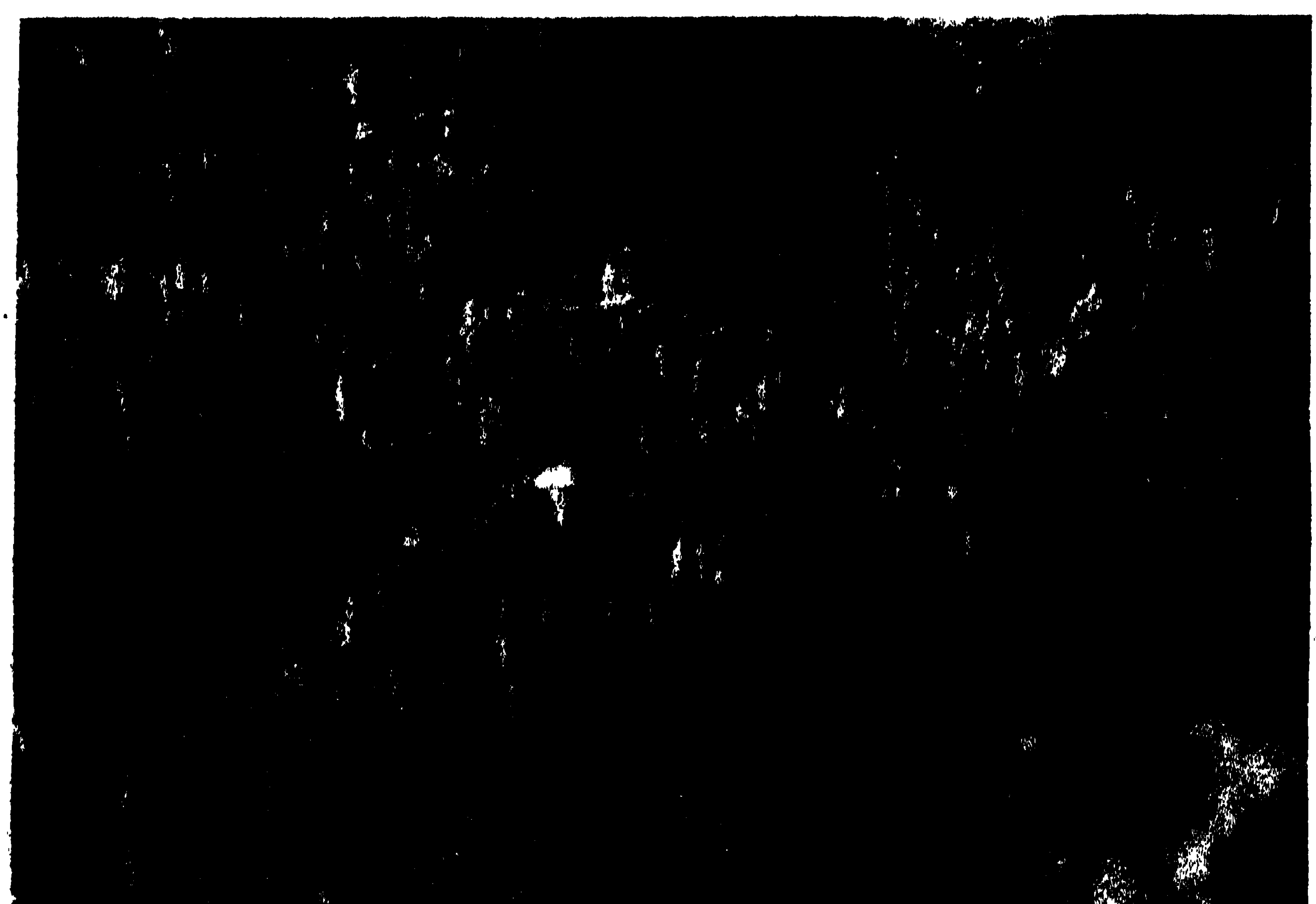
[1] Photographs by courtesy of U. S. Forest Service.

fully started with the intention of destroying the forests, are probably most difficult to prevent. A strenuous attack on the problem in one area, however, secured a reduction from well over 200 such fires a year to less than 20.

The organization needed to cope with the fire problem varies with the fire danger. Current measurement at established fire-danger stations of the factors influencing fire danger, and integration of these factors, together with fire-weather forecasts supplied by the U. S. Weather Bureau, provide a day-to-day basis for setting up an adequate fire organization. It has been evident that this system which permits the administrator to know in advance what fire weather may be expected and to take prearranged steps to meet the predicted danger has helped to reduce the fire losses.

Success in fighting fire depends on all those engaged in the job doing the right thing in the correct manner at the right time. In order to attain this each man of the fire control organization must be trained in the methods and techniques of controlling forest fires under a variety of combinations of cover types, topography and weather conditions; in proper use of tools and operation of equipment; in organizing and working crews of men efficiently. Added impetus to training within the past decade has prepared fire control men to handle their work with fewer errors and omissions.

As in practically all other fields of human endeavor there has been the same constant urge to increase the tempo and demand more speed in all the stages of action on a forest fire. Minutes saved in the early stages of fire can well mean hours of toil saved. The quicker one of the larger fires is encircled with a control line, the smaller the acreage burned, the loss and cost. Mechanization, which is growing in fire control work, in many



PARACHUTE JUMPER ON HIS WAY TO A FIRE
NOTE SMOKE OF FIRE IN LOWER RIGHT FOREGROUND.

cases permits the demanded increase in speed of either the attack or the control of the fire.

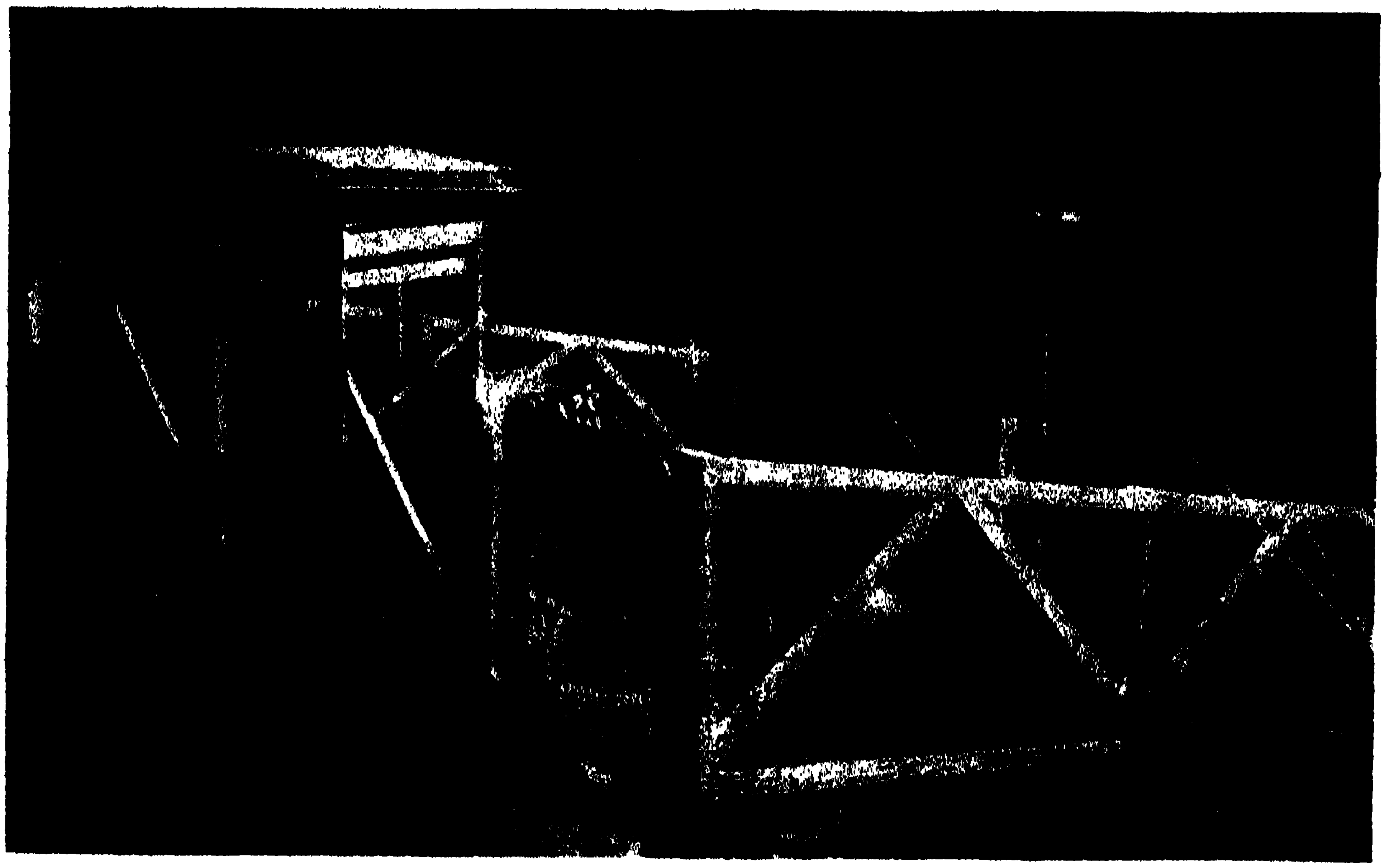
A large mileage of forest-protection truck trails (roads) built for fire-protection purposes in the past years by the Forest Service, the CCC and under emergency programs permits many fire guards to be motorized and to reach fires in minutes instead of hours as formerly when they had to travel by foot or horse. Portable radio equipment enables the guard to call back promptly from the fire in case help is needed or to let headquarters know that he is able to control the fire alone. Forces of men needed for suppression work are now transported by truck or bus over these roads to points as near the fire as possible. Previously it was often necessary to hike for hours and sometimes days to reach the scene of a fire.

Tractors, with a dirt-moving blade attached in front or dragging large strongly built plows, have come into widespread use in building the fire line on the larger fires, even in the more mountainous areas. Such equipment permits a fire line to be built at a much faster rate than could be accomplished by man-power. It also reduces the man-power requirements and is not subject to progressively decreasing production resulting from fatigue as men alone would be. As an example, in one national forest region in the past two summers, tractors constructed some 400 out of a total of approximately 1,500 miles of fire line on all fires which occurred in this area. Large logs are removed easily from the fire line or adjacent to it by the tractor. Formerly logs had to be cut in sections and rolled out by hand, a slow and laborious process, often impossible in the face of a fast-running fire.

Perhaps the most spectacular mechanization development in fire control is the use of the airplane. It has been adapted

PARACHUTE JUMPERS AND TWO TYPES OF PARACHUTE

PROTECTIVE SUIT AND SPECIAL PARACHUTE SHOWN ON THE BACK OF THE MAN TO THE LEFT. THE PARACHUTE ON THE FRONT IS OF STANDARD DESIGN, WORN AS AN ADDITIONAL SAFETY FACTOR.



FIRE DANGER RATING STATION, KANIKSU NATIONAL FOREST

to several distinct fire control purposes. For about two decades the airplane has been used after lightning storms or during hazy or smoky periods to search for small fires which may be burning in areas not visible to established lookout stations.

For several years the airplane has been used to drop supplies to suppression forces who are fighting inaccessible fires or isolated sectors of large fires. By means of simple inexpensive burlap parachutes all types of needed supplies, tools and equipment are dropped to the fire fighting forces. Short-wave radios to permit communication between the forces on the fire are dropped successfully and without damage. Even crates of eggs and prepared hot meals are delivered to the ground forces. Water is dropped in 5-gallon tins for thirsty fire fighters on ridge tops far removed from springs or streams.

One of the most important advantages of delivering supplies by airplane is that it enables the forces to bivouac on or near the fire line where the work is located rather than to waste from 2 to 4 hours of a 12-hour shift in mere walking over rough terrain and climbing to high elevations from the base fire camp to the distant fire line. Of equal importance is the fact that needed numbers of men can be placed on a fire immediately when delivery of essential food and equipment is assured.

During the fire seasons of 1939 and 1940 a total of over 500,000 pounds of food, tools and equipment was delivered by parachute in the western United States hours and sometimes days before mules could have delivered these supplies.

When the occasional large fire occurs on a national forest, there is seldom sufficient overhead personnel locally available to direct the efforts of the forces employed for the job. While the laborers needed to wield the axe and shovel can be recruited from nearby labor centers in a relatively short time, the overhead must be obtained from adjacent or even distant national forests. It is

TRACTOR TRAILBUILDER BUILDING FIRE LINE, LOLO NATIONAL FOREST

fruitless to place laborers on a fire unless trained and experienced men to direct their efforts accompany them.

Speed in getting overhead to the fire must equal that of recruiting the laborers. The answer to this is airplane travel. As an example, when last season 500 laborers additional were required to control a fire, it was possible for the laborers to assemble and to reach the fire within a few hours to be available for the next work-shift. The 50 overhead required to direct these men were not available locally but were transported by plane from national forests as far as 550 miles distant in less than 4 hours. If automobile, bus or train travel had been relied upon, this overhead would not have arrived for at least 12 to 24 hours and would have required a rest period from the fatigue of travel before they would have been capable of carrying out their assignments on the fire.

Parachuting men to fires in inaccessible areas is a recent development which has attracted much attention. Through extensive experimentation the technique of parachuting, landing in the desired location and the development of protective jumping suits, guidable parachutes and featherweight radios for use by the jumpers have been developed. A fire which would require many long hours of hiking over mountain trails or through well-nigh impenetrable cover can be reached in less than an hour by a fire fighter floating down from a plane. This saving in time, this increase in speed of attack means that one or two parachute jumpers can often reach and control a fire in a dangerous location while it is still small. Horse or foot travel to similarly located fires would inevitably result in a much larger fire, burning for days instead of hours, with attendant high damage and great expense to control.

In 1940, on a more or less experimental basis, two-man fire fighting crews parachuted to nine fires which were in especially inaccessible and dangerous areas, where under existing conditions fires would spread rapidly and become large

before usual suppression forces could reach them. Parachute jumpers were able to reach some of these fires in an hour or less. Ordinary modes of travel would have taken from 24 to 40 hours. The remaining fires attacked from the air were reached in from one to three hours, resulting in similar time savings.

As an example, on the evening of August 20, a lightning storm unaccompanied by rain hit the Moose Creek Ranger District in the Northern Rocky Mountain Region. Sixteen lightning fires were started in the area in which there were but 11 men available to handle the fires. Four parachute jumpers were dropped to two of these fires with the result that they controlled the fires when still less than one quarter of an acre each. Six of the remaining 14 fires were quite comparable in all respects to the two which the parachutists attacked, except that they were more readily accessible to roads. These fires burned from 100 to 1,000 acres each and cost from $2,000 to $13,000 to control as compared with the two fires controlled at one quarter of an acre each by the smoke jumpers at a total cost of less than $500. It is conservatively estimated that if ground forces had been depended upon, the cost of suppressing the nine fires attacked from the air would have amounted to no less than $32,000 as contrasted with $9,047, the total cost of maintaining the parachute suppression forces for the full season. Actual suppression of all these fires cost only $2,250, excluding non-firefighting time of the men when engaged in other work and awaiting fire calls. This indicates a net saving of almost $30,000 in expenditures with a reduction in area burned of several thousand acres.

Speed in controlling forest fires is also being advanced by the development and use of other specialized equipment such as portable water pumps, tank trucks, power fire-line construction machines, portable radios, power felling and bucking saws, power flame throwers for rapid back-firing of lines that must be burned out to stop the advance of the fire, small tractors for transporting small crews and supplies over trails where there are no roads, and other similar equipment. Equally important but less arresting is the increasing study and improvement of methods of working men on the fire line to increase production and to reduce waste effort and time commonly experienced in emergency work such as fire fighting.

Although considerable progress has been made, the losses are still too great. A loss of 318,000 acres per year, the 1940 burned area, would be equivalent to a loss in 10 years of over 3,000,000 acres, too great a depletion of our natural resources to be countenanced. When forests burn, productivity for the period until the resources lost are again replenished and available for use must be recognized as well as the monetary value of the resources destroyed.[2]

[2] The resources of the national forests and their importance to the welfare of the nation appeared in THE SCIENTIFIC MONTHLY for August, 1939, "Forest Conservation and National Security," by Richard F. Hammett, U. S. Forest Service.

ANT MOUNDS IN SUMMER WOODS

By Dr. E. A. ANDREWS

EMERITUS PROFESSOR OF ZOOLOGY, THE JOHNS HOPKINS UNIVERSITY

According to the old fable the grasshopper came to the ant to beg food which the industrious creature had stored up for the future while the grasshopper had spent the summer singing. And in the scriptures we read that the ant "having no guide, overseer or ruler yet stores up its meat for the winter." Yet this is not true of all sorts of ants and if we take as example the kind known as the mound-building ant of the Alleghanies, or to the entomologist as *Formica exsectoides* F., we will soon find that its chief concern is with its daily bread, with no reference to storage for the winter, and indeed we will come to realize that it is only its fine house and family that insures this kind of ant against the terrors of the winter.

A mound such as seen in Fig. 1 often swarms with ants much of the summer time; ants all running at such speed that the camera fails to show them, each working quite separately, here and there on the roof of their great community house, which is so vast as compared with the ant itself that the Reverend H. McCook calculated the great pyramid of Cheops was small work for man, in comparison. We see each ant struggling up the slope with maybe a stick ten times its length held up in its jaws, as if a man carried a telephone pole, or maybe a stone great in bulk and weight, but if not to be lifted then dragged behind as the ant runs straight backward and yet rapidly. Whether near the top, over the top or on this side, the ant suddenly releases its burden and runs down for a new load. Objects are picked up from fifty feet roundabout and brought to add to the mound which thus becomes, in close-up view, Fig. 2, covered over with small objects of many kinds looking like a sort of museum of what can be found in the neighborhood. Though thus gathered bit by bit by ants seeming to have no knowledge of the works of the others, yet the mass takes on the form we see in an hourglass where the sand falls from a central

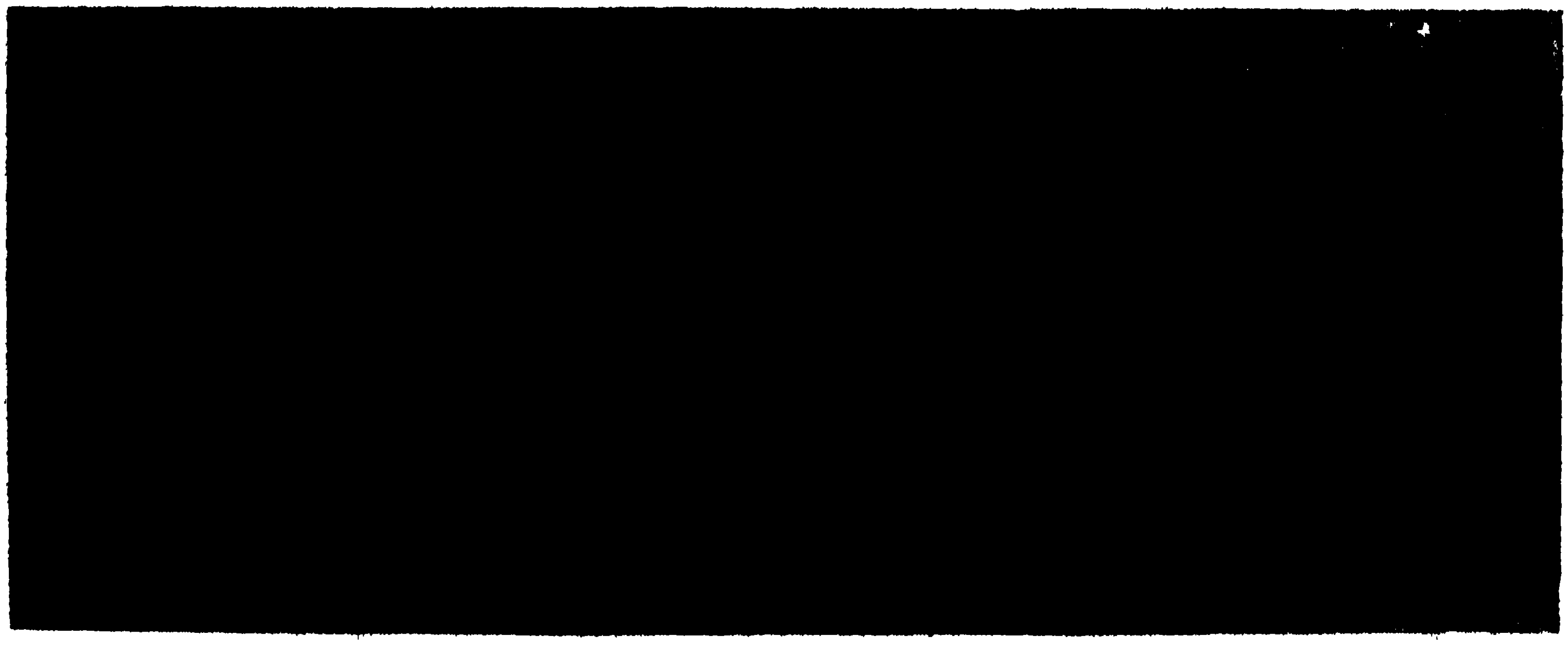


FIG. 1. AN ANT MOUND MADE PARTLY OF CHARCOAL

SINCE THE CHARCOAL BURNERS CUT THE FOREST NEW TREES HAVE SPRUNG UP AND THE ANTS HAVE MADE THEIR GREAT MOUND DARK WITH BITS OF CHARCOAL. THE SIX-INCH RULE GIVES THE SCALE.

point above. But for all this work the ant must eat: and ancient wisdom informs us that the ants "are a people not strong, yet they prepare their meat in the summer." Follow the ants far enough and you may see the way meat is got—some or many ants mobbing a worm or insect, eventually killing it and dragging it back to the mound, where it is lost to sight in some of the many openings round the bottom of the mound. But it is the liquid food the ants bring home that is their chief staple, and this can be traced to some tree inhabited by plant-lice or other insects that suck the sap and give out what is known as "honey-dew," of no use to them but welcomed by the ant as a substitute for milk. Each ant becomes gorged with honey-dew, and coming down the tree weighs a third more than when he went up.

All food, however, is not long held as private property, but it is shared with those who have less, till the entire community profits. Among the beneficiaries are the numerous young ants coming from eggs laid by the few mothers, known as "queens" who alone supply the community with new members to be fed and cared for by the working ants, which may be also builders and providers.

For the eggs and young certain temperatures are necessary, and here the ant seeks the aid of the sun. If we put thermometers into a mound, as in Fig. 3, we find out that the top is the warmer part, the north region the cooler and other parts varying as the day advances and the sun shines on different parts successively: while at night all grow cooler, but not as cool as the surrounding earth, since, as in our houses, there is stored up heat under the tight roof, lasting on into the next day.

That the ants do not only utilize the warmth of the sun but prefer certain temperatures rather than others, is

FIG. 2. A SMALLER MOUND
MADE BY ANTS TAKEN TO A NEW REGION. THE SURFACE IS COVERED WITH SMALL STICKS AND WITH WHITE SPECKS THAT WERE BITS OF FOSSIL SHELLS PLACED THERE BY THE ANTS. THE ANTS DID NOT PUT THE WATCH THERE.

known from keeping them in glass enclosures with thermometers and noting the places to which they carry their eggs and young; by finding the young in that part of the mound showing certain temperatures; and by sometimes seeing the ants coming out over the roof of the mound to carry their young to a more favorable part of the interior of the mound.

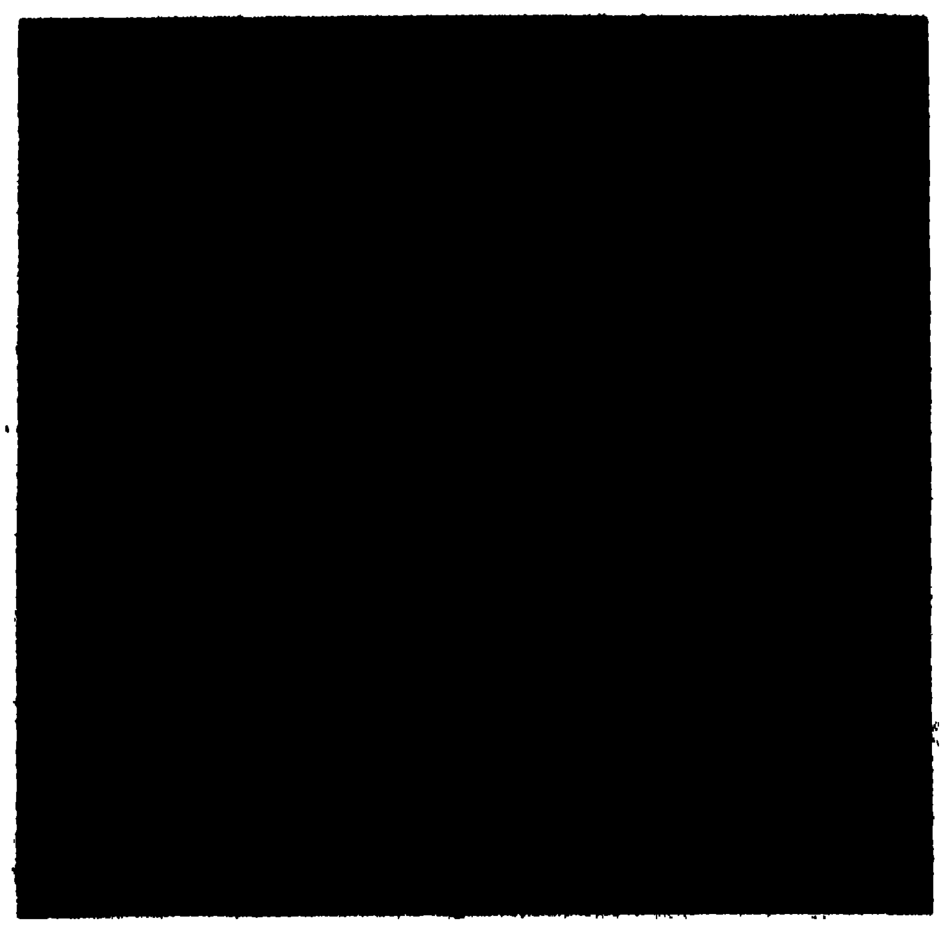


FIG. 3. TAKING TEMPERATURE
OF ANT MOUND. THERMOMETERS STUCK INTO A MOUND AND LAID ON ITS SURFACE TO TELL HOW THE HEAT OF THE SUN WARMS THE INSIDE, SO THAT IT IS FIT FOR REARING YOUNG.

FIG. 4. PARTIALLY MOSS COVERED
ALONG THE ROAD BY THE WOODS' EDGE THE MOUND IS THATCHED WITH FRAGMENTS OF PLANTS BUT ON THE SHADED FACE MOSS COVERS THE LOWER PART. THE RULE IS SIX INCHES LONG AND MARKS THE UPPER LIMIT TO WHICH THE MOSS HAS GROWN.

With food, with right sun warmth and with moisture most fitting, all goes well; eggs hatch as grubs, grubs rest in cocoons that look somewhat like grains of wheat, to emerge later as full-sized ants to increase the population from time to time in numbers to be inferred from tally of the cast-off swaddling clothes brought out by the old ants and deposited as frail additions to the roof, soon scattered by the winds.

The thousands of young ants added during the summer may more than make up for the losses by accident and old age; then the community grows and with it the mound is builded greater through thirty or more years. But this property handed down from generation to generation must be kept in repair; the rains tend to destroy it, and if the ants abandon it the mound soon becomes as in Fig. 5, covered with little pinnacles of firmer earth, the posts, columns and buttresses of the house, not as readily washed away as are the walls of the ants' chambers and passageways; but eventually all the mound will vanish and nothing but softer earth represent its site. Too much shade is bad for the community—they work best in the sun. The north face of the mound may be neglected and moss growing up over it, as in Fig. 4, may take entire possession when the ants migrate to some new site. It is true the ants do actually bite and irrigate with strong formic acid young trees and plants growing near their mounds, but yet trees will grow and may finally overshadow the mounds, so they are abandoned by the ants.

On the other hand, as old mounds disappear new ones may spring up, as in Fig. 6, where some kindly wind felling the trees made an opening in the dense woods and there the ants found a place

FIG. 5. IN MAY A MOUND LONG ABANDONED BY ITS INHABITANTS
WORN DOWN BY RAIN TILL THE SURFACE SHOWS LITTLE PINNACLES OF RESISTING EARTH AND SOME LITTLE PEBBLES NOT WASHED AWAY. THE SCALE AT TOP OF THE MOUND IS SIX INCHES LONG.

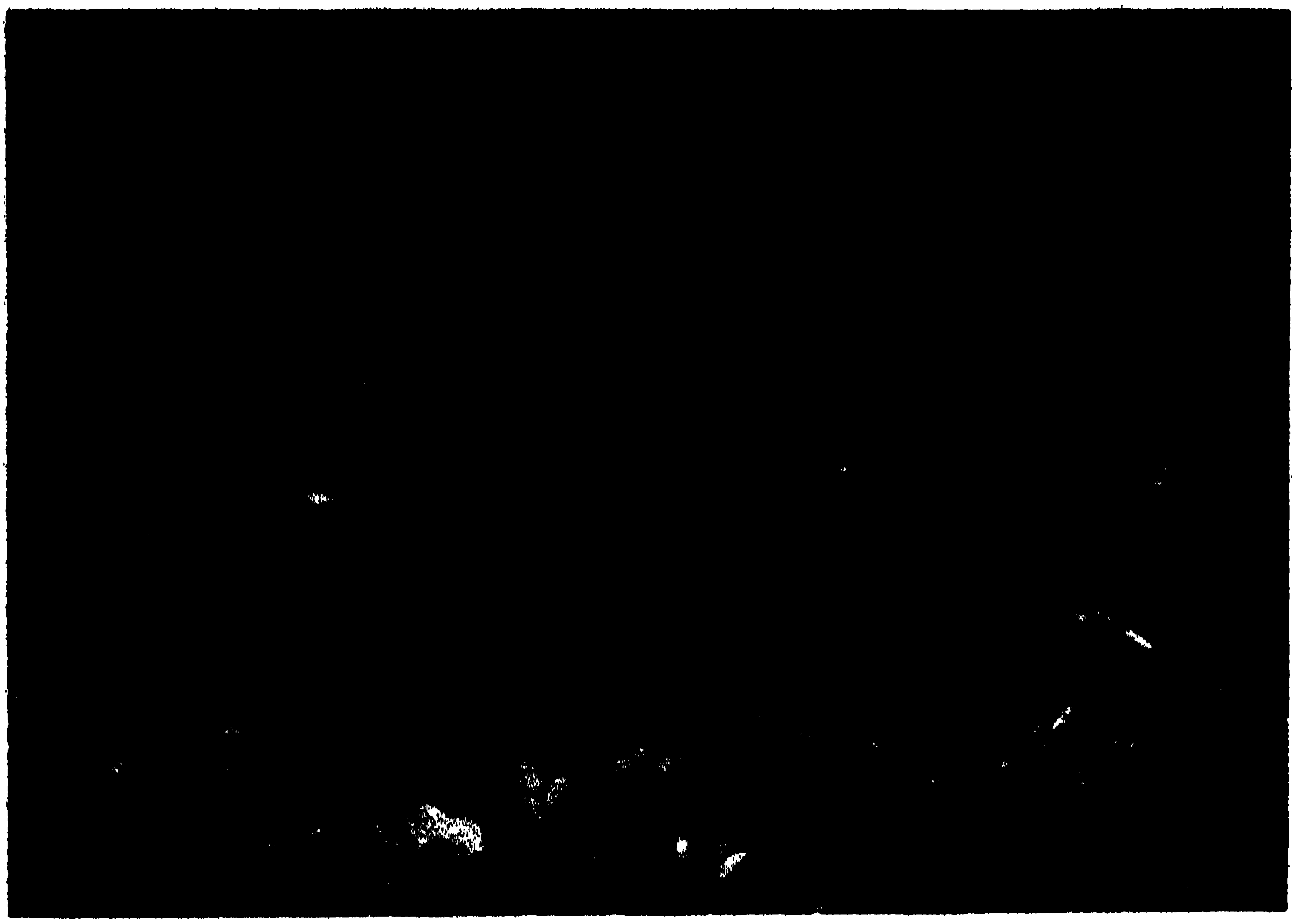


FIG. 6. ANT MOUNDS CROWD CLOSE TOGETHER TO ENJOY THE SUN WHERE THE WIND HAS THROWN SOME TREES IN THE PINE WOODS.

in the sun, not only for one, but for several mounds close together. Thus a preferred region may count hundreds of mounds, forming a city or state; mounds dying away here and new ones arising there, shifting the center of population, but ants living on in the same general region indefinitely.

PETROLEUM IN THE UNITED STATES

To an unprecedented degree, petroleum has become an essential in the waging of war.

The position of the industry, as to production, distribution and resources, and its capacity to expand and enlarge its services are of utmost consequence at this time. In 1940, production of crude oil in the United States was 1,351,847,000 barrels. This production was 63 per cent. of the estimated world's total, and 28 times the total production of the Axis nations. It came from 392,268 producing wells, of which 19,773 were completed during the year. Known oil reserves in the United States approximate 19,000,000,000 barrels, and the national inventory of petroleum products as of December 31, 1940, was 563,594,000 barrels.

Total transportation facilities included 316,000 miles of crude oil, gasoline and gas pipe lines; 146,900 tank cars; 140,000 trucks (all kinds); and over 400 marine tankers of 2,770,000 gross tonnage. Refineries in the United States having combined capacity of 4,181,000 barrels of crude oil daily were operating at the end of 1940, with additional capacity of 680,000 barrels daily shut down or building. In addition, cracking plant capacities capable of turning out 1,021,000 barrels per day of cracked gasoline were operating, with 130,000 barrels capacity shut down or building.

From the foregoing it is clear that as far as any probable national emergency is concerned the American oil industry is prepared. About an ample supply of crude oil to meet such emergency, there need be no concern. Transportation of crude from oil fields to refineries offers no problem. Manufacturing and distribution facilities are adequate to all needs, military and civil.—*Standard Oil Bulletin, April, 1941.*

THE CHARACTER OF WEATHER

By Dr. ADELBERT K. BOTTS

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WEATHER is capricious. It is fickle, undependable, inconstant. For the great majority of people in the United States the most apparent characteristic of weather is its changeableness. From January first until December thirty-first the weather provides, for most of us, a continuous, fluctuating succession of "spells," involving innumerable combinations of heat, cold, sunshine, cloudiness, rain, drought, wind and calm, usually with no apparent rhyme nor reason to the process.

Early man turned to the gods for his explanation of the weather. According to the temper and affection of the gods for their children, destruction and hunger or love and plenty were dispensed through the agencies of ever-changing weather. Having provided satisfactory explanations for the causes of weather changes, man's next task was to learn how to forecast the changes. Sages sought signs. A vast body of weather lore evolved. In the development of weather lore man acquired the rhyme as well as the reason for weather conditions.

When the wind is in the east, 'tis good for neither man nor beast.

When the wind is in the south it blows the bait to the fishes mouth.

These, with a multitude of local additions and variations, comprised the "weather prophet's" stock in trade. And we must not be haughty in our attitude toward prophets and their lingo, for, although often scorned by science, many weather proverbs have firm foundations in fact.

After reaching that happy state where he knew both the cause and the signs of the weather, man might have been satisfied. But he wasn't. Skeptics questioned not only the function of the gods, but the validity of the weather signs as well. Benjamin Franklin is recognized among the skeptics. His numerous experiments and observations led him to revolutionary conclusions. Besides identifying electricity as a phenomenon of weather, he is credited with observations which helped to establish the fact that storms tend to travel from the west toward the east.

From that idea gradually developed the concept of weather as a series of eastward-moving storms. With the aid of barometers scientists learned to identify storms with changes in air pressure. Eventually they devised a classification of storms based on barometric pressure conditions. The weather nomenclature of that period included such terms as "isobar," lines on maps connecting places of the same pressure; "cyclones," areas of low barometric pressure, more commonly referred to as "Lows"; and "anticyclones" or "Highs," areas of high pressure.

The United States Weather Bureau, originating in 1870, established its splendid system of observing, reporting and forecasting weather while the influence of the air pressure meteorologists was at its height. The Weather Bureau publishes daily weather maps on which storms are identified as "Highs" or "Lows," depending on whether high or low atmospheric pressure dominates the center of the storm areas. Careful analysis of pressure areas over a long period of years has taught forecasters to

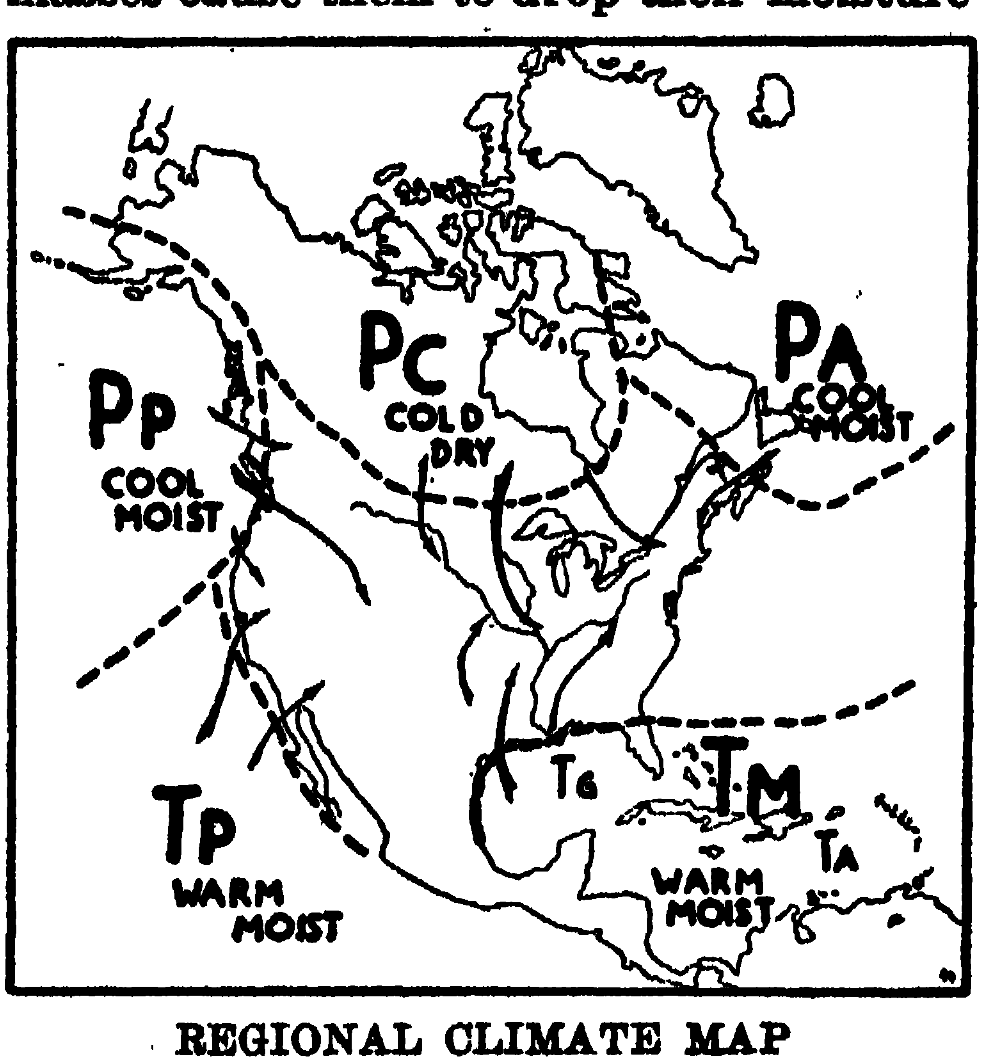
associate rather definite weather phenomena with "Highs" and "Lows" and with their various parts. Knowing the general characteristics, the paths and the usual rate of movement of storms, forecasters have been able to achieve a very high degree of accuracy in prognostication.

But again skeptics have arisen. Their activities have developed an "air-mass analysis" system of weather study. "Air-mass analysis" students contend that their system of weather study is more accurate and dependable than the "barometric system" because it deals with the whole atmosphere of a region rather than with a limited number of phenomena. Whereas the older system studied "High" and "Low" pressure areas, the newer system analyzes "air-masses."

An "air-mass" consists of a highly homogeneous body of atmosphere several hundred miles in horizontal diameter, three to five miles thick. Each "air-mass" is a separate and distinct individual possessing characteristics distinguishing it from its neighbors. Some "air-masses" are cold and clear, some warm and rainy, some cool and rainy; and a few are warm and dry. A succession of contrasting "air-masses" passing over a locality provide frequent and occasionally violent changes in weather within brief periods of time.

Air-masses affecting the United States appear to originate either in the high pressure zone lying to the south of us or in the polar high pressure zone. Masses from those two sources approach each other, generally arrange themselves in alternating succession, overlap along the zones of contact and march in an easterly direction across the country.

The character of any individual air-mass develops at the point of that individual's origin. Masses originating in the tropics acquire tropical characteristics; those from polar regions become polar in their nature. Oceanic air-masses are mild and damp. Continental air-masses display extreme temperatures and low moisture content. Each tends to maintain its original character as it passes across the continent, but its success in that regard depends mainly upon the speed at which it travels and upon the nature of the land surface over which it moves. A slowly moving mass is an inconstant mass. The land or sea over which it passes conveys to its lower layers many modifying characteristics. High mountains in the paths of air-masses cause them to drop their moisture



REGIONAL CLIMATE MAP

and often change their temperature as well.

Air-masses are named and identified according to their regions of origin. Perhaps the three most common air-masses visiting the United States are Polar Continental (commonly called Pc), Tropical Gulf (Tg), and Polar Pacific (Pp). In addition to these, others that visit our country are Tropical Pacific (Tp), Tropical Continental (Tc), Tropical Atlantic (Ta) and Polar Atlantic (Pa). If, because of slow rate of travel or because of obstructions in their paths, air-masses suffer modification they lose some of their distinctive

characteristics. Such changes in character necessitate changes in name. In such a manner a slowly moving, mild Pc (Polar Continental) air-mass becomes an Npc (Modified or Neutralized Polar Continental) air-mass. The Pc, as before, indicates the source and essential character of the mass. The N testifies to changes that have occurred in transit. All other modified air-masses are likewise identified by an N placed before the original initials.

The names indicate that dominant characteristics in air-masses are engendered by two sets of opposing factors. On one hand, polar versus tropical factors provide cold or warm air for the masses. On the other hand, factors of continental versus marine nature determine the severity or mildness of the temperatures as well as the amount of atmospheric moisture.

Continental climates are notoriously extreme in temperature conditions. If they are cold they are extremely cold; if hot, infernal. Usually, also, they are dry. As a consequence, air-masses moving out of a region with a continental type of climate possess extreme temperatures and low moisture content. Polar continental North America experiences extremely cold weather during eight or ten months of the year. At such low temperatures the atmosphere is unable to contain much water vapor. For those reasons the weather is clear, cold, crisp and dry.

As an air-mass moves out of such a region it transports to regions lying south and southeast of its point of origin a first-rate sample of McKenzie or Hudson Bay weather. Such masses are particularly frequent in the northern states during the winter. There they account for most of the clear weather and for the "unseasonably cold" weather. Occasional pure Pc (Polar continental) air-masses move directly from north central Canada to the Gulf of Mexico. On such occasions the newspapers are filled with descriptions of the "cold wave" and of "freezes" paralyzing the Gulf Coast and destroying the citrus crops of Florida. Such air-masses also furnish us with frosts on clear nights in early autumn and late spring.

Marine climates are generally mild. In winter they are warmer than continental areas of similar latitude. In summer they are cooler. Consequently, air-masses originating in areas with marine types of climates are less extreme in temperature than continental air-masses. Also marine air-masses are more humid than are those of continental origin.

But marine air-masses are not all equally humid. The contrast between those coming from polar regions and those coming from tropical regions is very marked. That is because warm air can contain more moisture than cold air. Thus, most of the rainfall of central and eastern United States east of the Rocky Mountains comes with tropical marine air-masses. Among that group the Tg (Tropical Gulf) air seems to be the most dependable and least erratic provider of precipitation. Tp (Tropical Pacific) air has little opportunity to serve more than a small section of the southwest because of the great distance to be traveled and of the high mountains in the path. Ta (Tropical Atlantic) air is, compared with Tg (Tropical Gulf) air, a relatively infrequent visitor but a most lavish spender of its liquid assets when it does come. On several occasions, warm, damp Tropical Atlantic air has moved directly from the sea into the northeastern states where it wedged itself in between stable, cold air-masses from the north. In such a situation it is literally accurate to say, "It doesn't rain but it pours." As evidence of the work of Ta (Tropical

Atlantic) air-masses are the New England flood of November, 1927, the New York flood of July, 1935, and the general flood of the Northeastern states in March, 1936, as well as the hurricane of September, 1938.

All parts of the United States have some variety in the air-masses that visit them. The far Northwest receives Pp (Polar Pacific) air most frequently, but Tp (Tropical Pacific) and even Pc (Polar Continental) air visits that area occasionally. The southwestern coast enjoys Tp (Tropical Pacific) air-masses more frequently than its northern neighbor; but it does not lack entirely the more stimulating air-masses from the north and from the continent. Southern California summer weather embraces some hot dry Tc (Tropical Continental) air-masses which originate in the arid region of Northern Mexico at that season.

Air-masses tend to move in an easterly direction, but once in a while they swing to the west or travel directly north or south before adopting the eastern component of their itineraries. Consequently, the western mountain section receives parades of Pp (Polar Pacific), Tp (Tropical Pacific), and Tc (Tropical continental) air-masses with winter Pc (Polar continental) masses for added variety. Throughout much of that section of the country Pp (Polar Pacific) and Npp (Modified Polar Pacific) air dominates, bringing heavy precipitation to the western sides of the mountains and mild but dry weather to the eastern sides.

The northern plains and prairies, eastern Montana to northern Ohio, add strong Pc (Polar continental) masses to the procession, while the southern states contribute Tg (Tropical Gulf) air. As is the case in all parts of the country the number and intensity of the dominant air-masses of these regions fluctuates with the season. The masses from the Gulf are more numerous and intense in the summer. Those of polar continental origin dominate in the winter.

To be sure, many of the weaker western air-masses lose their identity by mixing with larger and fresher masses before they reach the eastern states. Tp (Tropical Pacific) air and Tc (Tropical continental) air reach the eastern coast only on rare occasions. Pp (Polar Pacific) air is almost always modified by its journey over the mountains and across the plains.

In spite of these losses and modifications the northeastern states from Maine to Virginia are in a position to view the parade of air-masses at its most varied best. In that region it is an unusual month, indeed, which does not experience Tg (Tropical Gulf), Ntg (Modified Tropical Gulf), Pc (Polar Continental), Npc (Modified Polar Continental) and Npp (Modified Polar Pacific) air-masses. In addition to these "standard" masses a little pure Pp (Polar Pacific) and some Ntp (Modified Tropical Pacific) or Ntc (Modified Tropical Continental) air from the west may assert itself. From the east Ta (Tropical Atlantic) air, heavy with rainfall and Pa (Polar Atlantic) wielding a "northeaster" may join the procession and give added variety to the weather.

The ever-changing succession of air-masses passing over an area does provide an abundance of variety. However, the relations of one air-mass with its neighbors increases still further the complexity of weather probabilities. Between every two adjacent air-masses there is a zone of contact and mixture with a "type" of weather all its own.

Zones of contact and mixture between neighboring air-masses are called "fronts." The zone between a cold air-mass followed by a warm one is a "warm front," that between a warm mass followed by cold air is a "cold front." Air-masses differ in density primarily be-

cause of differences in temperature and moisture content. When they meet, the colder one being denser and drier than the other stays close to the ground and forces the warm, moist air along the edge of a warm air-mass to rise. In a warm front the warm air crowds into the rear of a cold air-mass. In that situation the warm air climbs up over the edge. The back side of the cold air-mass becomes a long gentle slope up which the warm air climbs as if it were climbing a hill, and the effects are almost the same. Warm fronts are usually rainy because as the warm air climbs the "cold air hill" it becomes cooled, clouds form and precipitation forms. But the warm front rains are not usually stormy. The processes involved in the climbing are relatively mild and seldom result in severe conditions.

On the other hand, cold front weather is nasty weather. As in the case of warm fronts, the cold air stays close to the ground and forces the warm air to rise, but in cold fronts the process is often a violent one. As the cold air advances into a region occupied by warm air it displaces the warm air by crowding under it. Consequently, the warm air, on frequent occasions, is forced to rise with rapidity and much turbulence. Turbulence results in local storms. The severity of storms depends upon the violence with which the displacement of air occurs and upon the amount of air involved. Cold front storms vary all the way from gusty weather to the most destructive tornadoes. Squalls, thunderstorms, hailstorms, "dusters," blizzards, tornadoes—all are commonly born in cold front zones.

Because of its frequent definiteness the approach of a cold front is one of the most easily observed weather phenomena in many parts of the United States. It usually advances from the west, accompanied by high, black, rolling clouds, and regardless of the time of day, may cause an abrupt and distinct reduction in the temperature. A five or six degree reduction of temperature within a few minutes is not unusual with the arrival of a cold front.

Weather does have rhyme and reason. It is difficult for us to appreciate the rhythmic sequence of warm and cold air-masses, especially when that sequence contributes to the making of such headlines as the following:

Relief Marshaled for South as Toll of Tornado Rises

135 Dead, 200,000 Homeless in Floods; Wheeling Deluged, Washington Hit, New England Cut Off above Hartford

Buffalo Area Gets 24 Inches of Snow
Soggy fall continues and city, out of removal funds, lets traffic halt

Cold Wave Moves East in Storm's Wake
Many towns snowbound in Dakotas

West Plagued by Dust Storm and Cold Wave

Thunderstorm Breaks Heat of 81; Cloudburst Floods Nyack as Dam Gives Way

In the midst of one of these phenomena we lose sight of the succession of related events contributing to its occurrence. It is only when observing the weather over an extended period of time or abstractly as on a map that we can truly appreciate the beauty of the system and realize that air-masses passing across the country do respond to definite laws of rhyme and reason.

THE REAL IN ART

By Dr. JAMES BYRNIE SHAW

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1. Creator and Created

In order to appreciate an artist's production one must reproduce in himself the living state of the artist when he created his expression. This means he must permit those processes in the artist's spirit and in his own which are essential in the creative act to have full dominance over him. This is easily evident in the mobile arts. A performer of a musical composition practically becomes its creator for the time; the dancer relives the ecstasy with each repetition. This is, however, just as necessary in the static arts. To see completely a statue or a painting, the spectator must become the vicarious creator for a while. The fundamental processes I shall label: *Eurythm, pose, poise, grace, personality, vision.* From their nature these are not the names of intellectual processes. They represent purely spiritual structures, living, changing, quite vague from an intellectual point of view. They are branching lightning-trees, lunar rainbows, vanishing ribbons of the auroral lights, lilies blooming out of the nebulous clouds over a mountain-top. But these spiritual structures are among the most real entities the human creature will ever find.

Eurythm will mean that phase of the creative spirit which leaves its stamp in the quality of a production called rhythm. Without eurythm in the spirit no rhythm would appear in the production. It is a directive agent, the inner pulse-beat, the cosmic wave of the spirit; for spirit palpitates even as matter or light.

Pose will mean that phase of the spirit which leaves its record in what we call design. It is the directive agent which places space-forms, time-forms, number-forms, color-forms, selecting the patterns they should exhibit.

Poise will mean that phase which directs the production of symmetry. The spirit must balance itself before it can create outward balance. It is the creative act of weaving threads of life into a net of symmetry, however intricate.

Grace will mean that phase which produces harmony. In the sway of its control the parts of a production fit together, are consistent, complementary, sympathetic.

Personality will mean the centralizing phase which keeps everything organic, unitary. It is the quality of identical persistence of the spirit.

Vision will mean the phase of the spirit which sees things not yet actual, which creates new spiritual forms to have expression in some medium. Without vision art would be impossible.

After a work of art has been finished, particularly in the static arts, it may then be made the object of intellectual study and criticism; but this is no more a study of art than the determination of the Fourier series for the crinkled groove in the phonograph disc is a study of music. The art is not in the statue but in the act of creation which gave birth to the statue. In this act must be found the reality.

Man is not entirely the product of "evolutionary" forces, for he has always defied the world that environs him by attempting to bend it to his will. Whatever his method of doing this and whether successful or futile, it shows clearly that he knows himself to be a creator, even though the material out of which he must

actualize his dreams as best he can is ill-adapted, inadequate or refractory. At times he is only too conscious that he is a leaf whirled in the eddying gust, but he has never accepted this fate. His very study of his environment is partly due to a gadfly curiosity, but it is due just as much, perhaps more, to his intention of becoming the master of the world, making it subservient to his wishes. For what? More food and clothing? More possessions? It takes little observation to see that these are usually secondary. What he is after is spiritual power: power to carry out his ideas, power to prove himself a builder, to give outlet to the seething forms that emerge far down inside him, in that inner life which is his most real life, the life that would be bound, inert, inactive, ineffectual, unless he acquires power to put it into some expressed form. He finds that outlet in creative activity: he may do it in the dance for rain, he may do it in Hamlet, or he may construct a slender stem holding a flower high up above the arid city street. Though he be tossed by the winds of destiny, though he may float on the river of heredity, he is not content with this. He is also an individual, something unique in the universe, and he has within himself an urgent inner life which must be let loose. He finds at times that his environment is too much for him, and he makes himself passive to influences outside his control, so that he may study them carefully, keenly, to penetrate their secret structure and to learn in what way and to what extent he can turn their turbulent currents into channels of his own. He develops his analysis of them, his imagined laws, his system of science, his constructs, finding within himself what matches them, so that he may go with them long enough to get command of them. But he knows intuitively that his place in the universe is not that of a mere spectator, seeing things only by "flashes of lightning,"[1] the rest all darkness and mystery. He is not a beggar-child looking wistfully through heavy plate-glass at the feast of the universe. Neither is he a walking-doll that says "mama" and goes to the ash-barrel when the mechanism is broken. He is an adventurer who is out on a quest of beauty. There is inside him an incessant longing—not always consciously known,—but yet persistently there—for an invisible, intangible, inaudible reality, which is more important to him than all the trumpery with which he may surround himself, for this reality is indeed himself. It is a glorified expression of that which he sees himself potentially to be. Whatever means of expression he finds will be as inadequate to express his vision as the paper and ink to carry an impassioned lover's rhapsody.

[1] Poincaré, "La valeur de la science."

When the first primitive tribe with sweating labor managed to stand on end a huge monolith, their expression of the majesty and power of their first vague intuition of the unknown, expression of their own dim consciousness of capabilities, of powers to be attained only in the tedious march of centuries, a monolith reaching up higher than they, solid and undisturbed by rain or frost, was there nothing real and permanent for which this clumsy symbol stood? Even the archeologists and ethnologists who see in it nothing but a phallic symbol will have to admit that the insurgency of life and the urge to creation are worth a symbol which shows them as eternal realities.

The two-fold character of the psyche is easily evident with only a small amount of reflection and very little insight. There is the ability to crystallize the evanescent and flowing waves of events into definite and stable forms, and this is called knowledge. Then there is the constant urge to create new elements, more spontaneity, unguessed and undreamed forms for the inner life, and this is called art. So fleeting is the configuration of the psyche that the fixed and stable elements are ascribed not to

it but to an objective world which is assumed to be independent of the psyche. Knowledge is assumed to be understanding of an extraneous entity. Art is assumed to be mere play of the spirit, fleeting emotion, of only passing interest. Both assumptions are wrong, since knowledge is the more or less temporary system of invariants with which the psyche plays, while art is the emergence of the new life-forms of the psyche itself. Those creations of the psyche which it retains for a while constitute knowledge, and the creating of a new form is art. It is easy to restate knowledge since its forms are for a while permanent, but to state art one must accompany the wild duck in its flight, must freeze the rainbow the sun produces against the shower of events. This means of course that knowledge and art are human, even if they plumb the absolute. What sort of psychical material a Martian cherishes as knowledge we can not know. What sort of art he creates we can not know either.

The stable routes from one item of knowledge to another we call logic. They seem to us to be necessary, but merely because we have made them habitual in going from one judgment to another. To find other routes would be an act of creation, which would be art, not logic, and this process of making new logics is actually going on. Stable modes of art would be impossible, since creation implies the unexpected, the versatile, the ever-new. This does not mean that in the creative process there is not a permanent reality. Reality does not mean fixity, crystalline structure. Any organism that maintains its individuality as an organism, even though subject to a steady flux of material, even if every atom, material or mental, is changing momentarily into a new atom, is nevertheless a reality. The human body is a reality, the immaterial sieve through which chemicals flow. The reality of art is of this nature. An easy example is dual symmetry, both complementary phases together constituting the unitary symmetry. This may be found in positive and negative number, in geometric reflection in a plane mirror, in sine and cosine, in wave and particle, in the façade of a temple, in the right and left of the human form, in the purple and yellow of the sunset, in the assonance and dissonance of music, in the earthly and the heavenly love, in male and female, in good and evil—what matter the medium in which the dual symmetry expresses itself? The reality is that which generates the symmetry; the forms are adventitious. The stable *idea* of symmetry is knowledge, the *actualizing* of symmetry in some form is art. Indeed knowledge and art are phases of a dual symmetry in the psyche itself, though there are also to be found trinities, quaternities and many other forms. The struggle of the poise of the spirit with its medium of expression is often intense: "white, white blossom, fall of the shattered cups day on day."[2] To many of the realities of art there do not correspond ideas; they are not expressible in the abstractions and static forms of language. The nearest approach in language is in creative, metaphorical, suggestive poetry. Hence stating an example in words is very inadequate. It is at best a sort of ticket for reality itself. "Art is the very flowering, the tangible flowering, of the creative soul come to ecstasy."[3]

There is a constant interplay of the two characters of the psyche. It is the creative character which furnishes knowledge its hypotheses, the most steady source of advance in science. It is the crystallizing character which furnishes art its types of expression, the most steady source of production of art works. Research goes on all the time both ways. On the knowledge side it usually consists in an increase in dispersive power, splitting principles into more universal prin-

[2] J. G. Fletcher, "White Symphony."

[3] S. Cheney, "The New World Architecture," p. 347.

ciples or more fundamental hypotheses. On the art side it usually consists of experiments made to find a more adequate method of handling the medium, expressing more fully the artist's vision. Often the apparently unrelated researches spring from the same source deep down in the psyche. It has been pointed out that much modern art is an actualizing in art forms of the same universal invariants as appear in science in the Einstein theory. Human life, after all, is unitary, and we should expect this symmetric dualism in its manifestations. When crystallizations made by the psyche no longer fit experience we have an advance in science. When forms used for art no longer convey the message of the artist we have an advance in art. Neither advance is welcomed by the multitude, for the usual human being is Faust, always seeking the moment he will bid to stay because he has found his supreme desire. Man is still quite hairy with his past.

A few years ago a picture labeled "Life" hung in an exhibition. It was not large, but the canvas was a confusion of gaudy patches of yellow, green, blue, red, in chaotic arrangements and vague outlines. A bystander remarked, "Look at it! Did you ever see anything so crazy?" The reply was, "Is that a beef-steak in the center or a volcano in eruption?" Other comments were similar. Yet the artist in his conventionally jangling colors, his disorderly arrangements, his unformed outlines, really portrayed vividly the struggle of the eurythmic, the pose, the poise, the grace, the vision really inherent in the spirit of man, with the clumsy, stumbling, disharmonious unbalanced environment after the war. An erudite volume would not have made it as plain. "Art may tell a truth obliquely, do the thing shall breed the thought." "So may you paint your picture, twice show truth, beyond mere imagery on the wall,—so, note by note, bring music from your mind, deeper than ever Andante dived,—so write a book shall mean beyond the facts, suffice the eye and save the soul beside."[4]

A work of art is the exhibition of a significant form in which the creative spirit of the artist incarnates itself. Its purpose is to effect a transfer of some part of the spirit-life of the artist over into that of his public. In the static arts the flame of creativity is frozen in its flickering, but an intense moment is chosen so that the unchanging exhibition will always suggest the lambent fire. In the mobile arts a portion of the creative life is caged and placed on exhibition, and may be reproduced many times. The dance, the drama, music, mobile-color, give us a chance to live the life of the artist for a few exalted moments, caught up in his ecstasy, feel his rapture, and glimpse eternity.

> Presences plain in the place: . . . a flash of the will that can, . . .
> Existent behind all laws: that made them, and, lo, they are! . . .

until we say:

> Well, it is gone at last, the palace of music I reared, . . .
> I feel for the common chord again, the C major of this life. . . .[5]

Art is not concerned with life as life, any more than mathematics is flowering for astronomy or physics, but with that essence of life which is in the ever-changing structure of the spirit. Art is not primarily concerned with value, though values will be attached to its products, just as to the products of the intellect. It is not the function of art to moralize, but to set forth the character of spontaneous potentiality in the spirit. When he carved in stone Villon's poem, Rodin expressed in "The old courtesan" not the miserable end of a misspent life, but "the antithesis between the spiritual being which demands endless joy, and the body

[4] Browning, "Ring and the Book."
[5] Browning, "Abt Vogler."

which wastes away, decays, and ends in nothingness."[6] Art is not concerned with penalties but with creative expression. It seizes and passes on to us the structure of pure form, the reality in spirit. Knowledge may evolve from stage to stage, but art can not evolve. It expands, flowers in new blossoms, creates new universes.

> Art is not susceptible of intrinsic progress. From Phidias to Rembrandt, there is movement but not progress. The frescos of the Sistine Chapel take absolutely nothing from the metopes of the Parthenon. Retrace your steps as far as you like,—from the palace of Versailles to Heidelberg Castle, from Heidelberg Castle to Notre Dame of Paris, from Notre Dame of Paris to the Alhambra, from the Alhambra to St. Sophia, from St. Sophia to the Colosseum, from the Colosseum to the Propylaea, from the Propylaea to the Pyramids: you may go backward in centuries, you do not go backward in art. The Pyramids and the Iliad remain in the foreground.[7]

The events of art are the aspirations of the spirit, and the invariants of such events are hopes. They furnish a system inherent in human life just as valuable for profound study as the invariants of the phenomenal world. When hopes are organized into a wild bird of the spirit ready for its flight, they become visions. Through the centuries these have been the dominating factor in the life of man, not the fogs of his swamps nor the rain of his tropics nor the crags of his fastnesses, nor the blue-white sun of his deserts. Through the acquisition of knowledge we attach our tentacles to what the psyche has made stable for itself. By the enchantment of the artist we receive the power of new life. Art is an offering of a sacramental communion of one personality with another.

II. Mathematics; Creator of Frost-Flowers

Sandburg said poetry is the achievement of the synthesis of hyacinths and biscuits, and we may read mathematics instead of poetry, because mathematics is the child of the creative power of the artist and the crystallizing power. Many times mathematics has created new worlds, and developed them intellectually. Some forgotten genius saw the reflection of ordinary numbers, and created negatives, opening a vista to a new infinite horizon. Then another genius saw an infinite plane of worlds of number all radiating from the central zero; and a century ago Hamilton saw this center sparkling with rays in all directions. Since that time the worlds of number have become infinitely numerous, and the intellect has work for centuries. When the school of Pythagoras stood appalled before the first irrational known, they little guessed the swarms yet to appear. When a rebellious youth named Galois looked at the roots of equations, he saw they were arranged as petals of more and more intricate flowers, each made from the conjugate sets of roots of special resolvent equations, each conjugate set generated by a single irrational, the whole furnishing a glowing corolla, a unitary work of art. They were like sets of dancers when the group of the equation began to act, going through patterns tangled but describable in terms of a few fundamental changes. The defiant quintic was tamed, and its twelve pentads, or twenty triads, or thirty dyads, connected together, gave all the recurring cycles of the dance. Some day we may see a Ziegfeld producing the "Dance of the Quintic."

When Lobatchevsky created a new world of space it did not take long to create many other new worlds of space, worlds bizarre to common sense. They furnish hundreds of crystallizations called theorems, and have even suggested to the scientist better patterns to hang his phenomena on. Four-dimensional geometries and others have appeared, full of latent possibilities for new designs for artists. Indeed, much modern art is based unconsciously on such space harmonies. They spring evidently from a common

[6] Rodin.

[7] Victor Hugo, "Shakespeare."

source, though expressed in art forms or studied by the intellect.

Bernoulli created expansions of functions in powers of the argument, and later Fourier in series of trigonometric functions, but they did not see the host of new and startling functions thus born into the world. Their successors created more worlds of functions, and the day came when one such world called "wave-mechanics" was all that was left of a definite character in modern physics. The linear operators which furnish these expansions are intellectual forms which arise in the living transformations of the spirit itself. Under their magic we see the world of matter bending into new shapes, and even if it is an inanimate world these forms have an intrinsic beauty of their own, which is what fascinates the physicist. The study of these operators shows that while change may be expressed in an infinite and continuous series of manifestations, yet in the changing itself there may reside a permanent and stable essence, the structure of the operator itself, which is ultimate reality. We finally see the entire collection of different instants simultaneously, just as we visualize a differential equation by its field of characteristics, or just as a musician can grasp a whole symphony as a single unit, a timeless form. The futurists undertook to do the same thing in painting for motion, presenting together a succession of different experiences, thus suggesting the unified experience as a single undivided whole.

Kempe defined mathematics as the science of pure form, and C. S. Peirce as that subject which studies ideal constructions. We might then be tempted to consider all art as consisting of branches of mathematics. There would be some justification for this in much modern sculpture, painting and music. But we must not forget the distinction pointed out at first, between the two modes of knowing, one studying the crystallized product, the other the process of creating. Mathematics makes pearls, art living tissue. Artists themselves are sometimes confused as to what art is, when they neglect this distinction. If one studies the forms created by musicians he is not then an artist. He might write a quite mathematical treatise on the subject. Neither is he a musical artist if he merely gives expression to what has already appeared in a different form.

It is the function of the intellect to examine the cold product of the artist, and such study may deceive the student into thinking he is studying art. It is the function of the intuition to seize the essence of the creative act, to experience directly the thrill of creation of course, but in the rich complex of emotions to perspicate that which is not emotion nor thought, but a permanent and abiding reality, the very essence of the spirit as it dissolves into a new seraphic body.

The question whether mathematics is true, or whether a work of a painter, poet, sculptor, musician or dancer is true, is without much meaning. All it can mean is an inquiry as to how far the form of expression chosen adequately conveys the artist's dream. For instance, Riemannian geometry is true, so is Euclidean. They are both creations. A Gothic cathedral is true, so is the Empire State Building. The Moonlight Sonata is true, so is the Rhapsody in Blue. One does not ask whether an orchid is true, though it does not resemble a lily-of-the-valley. Both are expressions of creative energy. One of the delightful qualities of art is the variety of ways in which the same ultimate reality may be expressed. All the art, all the mathematics, all the science in the world could be destroyed, and humanity would start the next day to produce more, very likely utterly different from what has been before, but yet just as true. The reality in mathematics is in the spiritual energy locked up in its crystal-

line flowers, and if they melt in the sun, the same energy will flower anew in other forms.

III. Poetry: Creator of Silent Songs

Sea-violins are moving up the sands,
Curved bows of blue and white are flashing over the pebbles;
Hear them attack the chords: dark basses, rising trebles,
Dimly and faint they croon, blue violins.
"Suffer without regret," they seem to cry,
"Though dark your suffering, it may be music,
Waves of low sound that wash the midsummer sky,
Sea-violins that move across the sands."[8]

Poetry is twin-sister of mathematics. Mathematics is wordless poetry, and poetry is mathematics in words. Both are essentially independent of the senses, though both use visible or spoken symbols as a means of communication. While mathematics talks largely in terms of concepts, poetry talks largely in terms of memories and images. The use of any kind of language is symbolism, so both use symbolism. Both speak in metaphors, for the particular statement made is pregnant with meanings not stated.[9] The significance flowers and fruits continually long after the first statement. "Poetry is the arch from inspiration to appreciation."[10]

Poetry is somewhat more concrete than mathematics, its symbols more associated with actual living. In the quotation above the endless beating of the sea, the distant horizon, the flashing blue and white, the music of the waves, the overarching sky, are symbols full of meaning to those with experiences. The endless beating of the years, the mysterious horizons whence time emerges, the aspirations, the defeats of the days striking against the hard unformed facts of life, are rich to those who have lived and open far vistas to the young.

[8] John Gould Fletcher, "Black Rock," p. 90.

[9] *Cf.* Scott Buchanan, "Poetry and Mathematics."

[10] Claude Chauvière, "Colette."

Is it necessary to repeat the reality the poet is living as he sings? This reality is the underlying music, the symphony which human life may be, despite the daily monotony, the petty swash of the environment, the apparently inert pebbles played on by the ocean of circumstance. Is this symphony any less reality than the ceaseless whirl of nebulae or the pulsating ultra-microscopic fogs called electrons? Is it any less important to point it out with an accompaniment of emotion which will carry it into the lives of the readers as an effective force, than to quote the latest cold statement about the supposedly expanding universe? Since the poet states his vision in words, can we argue that the artistic form is unnecessary? Not at all. The stark philosophic statement has no living appeal, is abstract, is part of an argument which proceeds in straight lines to a conclusion. The poetic statement is "a succession of curves, the direction of thought is not in straight lines, but wavy and spiral."[11] There must be rhythm, order, symmetry, harmony, unity and ideality, themselves due to the characteristics of the spirit when creating, as mentioned above. The technique of the poet is part of his art. If spirit knew how to pass its creations consciously directly to other spirit, technique and media of expression would be unnecessary. The abstract words alone fail to convey the full message of the poet. Abstraction gives at best a gauzy illusion which simulates reality. Intellectual comprehension is an anatomist beholding a corpse. Intuitional appreciation touches the living body.

What the artist does for us is to grow an evanescent flower, blowing but a moment, fragile, yet the focus of an intense creativity. If the poet can so assemble words that they catch us up into a whirl of intense flame, make time cease to be, external things to vanish, open an illuminating insight to distant isles, emerge an

[11] J. G. Fletcher.

ecstasy to carry the spirit up and up, until life, the world, the self, everything is seen by a supernal light and from a sublime height—then he is a perfect artist. The limitations in doing this by words only are heavy, the butterflies are weighted down by their wings, and even after these many centuries the poet has not yet full command of his medium. New visions appear and new modes of writing poetry must be discovered. The modern poet is not transcribing emotions nor depicting bits of raw experience, but is incarnating in a body of words those spiritual forces which are creating new organisms out of the life of to-day, welding together new groups of humans, evoking a new civilization, a new humanity which is not going to be crushed by the machinery and the financial systems of to-day; new forms of personality capable of dominating the enormous material power turned loose in past decades; victorious spirit flying freely over the maelstrom of seething energy, and in the cyclonic whirl of disorganizations generated in the chaos of war. Are there realities in art? The artist sees only realities—realities which would drive man mad, gaunt demons that haunt his soul, grinning gargoyles that look out over the tragedies in the city of civilization, insidious specters floating over the landscape bringing woes and desolation: realities that man himself creates day by day, wittingly or not; and also realities that have the serenity of gods, joyful Ariels of adventurous youth, triumphant angels of a transfigured world. We are in a creative renaissance, and one must expect the dream-intoxicated artist to find queer unusual forms for expressing his coruscating life.

I was taken and enveloped in a cloud,
Winds awoke and called me far away.
Now I wave a veiled farewell
To the lands I knew and loved,
To the crimson sunset, resting far off on black mountains,
When there rises the full moon
I shall sail rapidly in the waning light,
Hearing underneath me the swift billowy rush of spray.
But the white cloud, milkily crested,
Shot and throbbing with pale fire,
Whirls me over infinite oceans
Which the gates of back-flung sunset let escape.[12]

Drama: Creator of Invisible Rhythms

Poetry steps out on the stage in human form, and becomes a mobile art, the drama. Tragedy, comedy, religious ritual, the first expression of man's religion, expanding through the ages into what we see on the modern stage, commercialized, cheapened, degraded, occasionally etherealized, it remains a great art. Much of the stage production to-day is of course relaxation from the hurly-burly of present-day life, taking us out of ourselves for a little while—and indeed that is one thing art is for—the drama may point out serious problems in morals, may initiate us into forms of life beyond our reach, may take the place of the church, may be the only means of recreation, but it is none of these as a work of art: as art it is a complicated form in which we see expressed deep realities of the artist's spirit, those cadenced or broken eurythms accompanied by passions. This becomes evident in some of the modern abstract theatric art, often assisted by the other arts to produce a complex form. "Pelléas and Mélisande" in proper settings, with Debussy's wistful music, brings mystery, exquisite beauty, meaning too deep for words. "The Beggar on Horseback" with its dream-like character, fantastic stage-setting and lighting, and acting not meant to be realistic but metaphoric, expresses an innate beauty which is hinted at in the inset pantomime. "Lysistrata," recently shown in very unconventional setting and acting, purposely exaggerated in some ways, presents a fine example of Hugo's remark that art never grows old.

[12] J. G. Fletcher, "Black Rock," p. 16.

Though they may appear startling, daring, shocking, fantastic, unreal (whatever adjective may be used to indicate that the soul has been stirred out of drab monotony), modern theatric art will no doubt some day culminate in a work of supreme beauty, holding immense audiences breathless, spell-bound, silent, swept out of time, infused with new eurythm, seeing the spirit in a new pose, with new poise, full of grace, abounding personality, and with a vision of a glorified new life for man.

IV. Architecture: Creator of Musical Crystals

Architecture is an art far removed from the subtleties of mathematics and poetry, for it deals with matter directly in great masses, grouped into buildings, usually designed for utilitarian purposes. Here artist and engineer meet, and lately the engineer has been the artist. We might pause to consider whether architecture has the character we have insisted upon, expressing realities of the human spirit. But it becomes evident that we do have a definite reality appearing here, which may be called the timelessness of the spirit. The human race has always felt that there was an indestructibility in the spirit, and it has tried to express this in towers of Babel, pyramids, gardens of Babylon, temples, cathedrals, tombs. If man were really convinced that he is but a bubble poured by the Eternal Saki, he would live in any kind of shelter that would answer his needs. He would have no incentive to contrive architectural beauty. But he knows himself as outside the flux of time, he feels his power to build things that will last, since he has himself the lasting quality, and his architectural products are symbols of that which is inadequately called "his character." In his buildings he leaves a record for his posterity of his aspirations.

Louis Sullivan says:

> Men have ever felt the need to build. As they built, they made, used, and left behind them records of their thinking. Then as through the years new men came with changed thoughts, so arose new buildings in consonance with the change of thought—the building always the expression of the thinking. Whatever the character of the thinking, just so was the character of the building.

The architecture chosen for the world fairs of to-day exhibits the character of to-day. The new "sky-architecture" of America is an exhibition of the new life appearing in the western continent. It is organic, arising out of the purpose it has to fulfil. It is simple, stripped of convention and useless ornamentation. Life has become that, conventions are dissolving, artificial taboos are laughed at, and modern life in every way is becoming more naked and unashamed. The steel girders which support life are left visible, glass walls let light into living, and also show the world that what goes on inside is nothing to be hidden. Modern architecture represents downright honesty and simplicity. By the lavish use of color and lighting effects it expresses the joy in living. It exhibits those hidden realities in the spirit of man which we call organizing power, dominance of mind over matter, arrest of decay. So far as it transcends the organizations of the past centuries it points out the essential character of our new civilization of frankness.

Most of us recall the marvelous dream of Eliel Saarinnen for the building which should have represented the modern newspaper as the daily expression of the life and dreams of several millions of people. Perhaps the present building does that only too well! Is the poet right when he says:

> Though food be scarce and drink be lacking, though labor be in revolt and trade be declining, America will go on finding its visions in the mist that hangs unstirring, though through and beyond it come the loud crash of waves shaking the granite, beating like inexorable drums of fate, sounding boom on boom;—each one a minute-gun to mark the years that must elapse before the moment of its doom.[13]

[13] J. G. Fletcher, "Breakers and Granite."

We may have hope, however, when we survey the newest architecture, mammoth and massive as Arizona buttes and canyons, or slim and straight as it soars into the sky, reminding us when in color of the everlasting rock in the desert which defies sun, time, wind, weather, petty centuries, and like the temples of the Grand Canyon, the same yesterday, to-day and to-morrow. We even feel in these structures that all the rackets, gangs, crime and rotten politics of the cities can not really destroy the life of the people, for it is at bottom mammoth, massive, rich in color and aspiring towards the light.

Sculpture: Creator of Sleeping Beauty

Sculpture uses solid material to express its vision of the realities of the inner life. It waves a magic chisel and the princess lies enchanted, motionless, until the prince appears. Sometimes it is on the side of a mountain or in a block of marble, or it may be a mass of wet clay, even a bit of carved ivory. The form may be the Sphinx, an Aphrodite of some forgotten Greek, the "Kiss" or the "John the Baptist" of Rodin, a bas-relief of Aristide Maillol, a distortion of Archipenko or an abstraction of Duchamp-Villon. But in every instance the sculptor is trying to put into the sleep of three dimensions a creation which comes from his own eurythm, pose, poise, grace, personality or vision. In different sculptors these realities may have different emphasis. When he sees man as the creator of his own body, a daily sculpture, the epitome of all principles of art, he may put into stone Browning's verses:

For pleasant is this flesh;
Our soul in its rose-mesh
Pulled ever to earth, still yearns for rest.

Let us not always say
Spite of this flesh today
I strove, made head, gained ground upon the whole.

The sculptor realizes that the body is itself a manifestation of the spirit, the creator which organizes chemicals into human forms. So he has typified thousands of times in his statues of man and woman, strength, power, defeat, vague aspiration, sheer loveliness. The dancer is arrested in her pose, yet showing the rhythm, with the moment before still warm, and the moment to come heard breathing. The sculptor does not make dead things, his statue is sleeping, not lifeless. Presently it will stir, and new life will emerge from the dreams of that sleep. He chooses a significant sleep so that the great fundamental invariants of spirit may be seen when in transitory motion they might be missed. He uses his masses to convey properties of life; life caught for a moment in repose, one phase of the rhythm ever present. And when love inspires Pymgalion Galatea shall awake.

Painting: Creator of Singing Light

We lose solidity in painting, though we may create the illusion of it, but we gain the subtlety of color, and the chords of color we may strike from the prism. The gain is at the risk of a sense-reality which may hide the spirit-reality that the painting is to exhibit. A painting may copy nature or some aspect of humanity so faithfully that it is deceptive, and we catch the scent of the flower in the field and start to speak to the person. It may even become a perfect anatomical or psychological study. Then its external reality is a will-o-the-wisp to lead us into the swamps of the subject. This is so great a danger that some modern painters have avoided painting any subject at all recognizable. Also the scene depicted may stir our sympathies or our memories, and we tell ourselves a tale, jovial or heart-breaking. This is perhaps the function of the novelist, but it is not what painting is for. "The Rake's Progress" may be a good sermon, but it is not for

that reason good painting. Then again a painter may have such extraordinary skill with his brush and palette that he imitates flesh or tapestry almost perfectly, but mere dexterity does not produce a work of art. It may make a shadow photograph in color which reminds us of the original and which we love to look at and to live with. But this is not the purpose of painting.

If one studies the wonderfully flowing lines, the balanced curves, the unified composition in Georgia O'Keeffe's "Lake George" he cares little what lake it is or if it is a lake at all. In her "Cos-Cob" there is no intelligible story, but the masterly placing of musical ripples and flowing winds is a study of the eurythm and the grace of the spirit itself. And in her "Music—black, blue, and green" she has made the spirit itself visible in an act of creation, in color and composition that sings. In these paintings there is little to distract us from perceiving the reality. We have a view of beauty herself veiled in diaphanous gauze. In the last-mentioned there is even a glimpse of ecstasy, an all too rare reality, yet vividly real and abiding once attained.

The painter uses colored spaces and lines of drawing, but they are passed through the magnetic field of his esthetic personality and come out curved into more than color and line. There is added what artists call "the fourth dimension," a term borrowed from mathematics. The forms are idealized in a sense similar to the mathematical sense, not in the ornamentalizing sense. This kind of idealization is a perspication of the essence of the form, and vivifying it into a body for the spirit-reality. When this takes place it may happen that there is introduced a distortion from what would be expected in a naturalistic, unidealistic painting of "things as they are." But this is often necessary in order to produce the expression desired. Whatever one may think of paintings in which parts of objects, geometric figures and other fragments are placed in queer positions on the canvas, after all it is not very different from the mathematician's various projections of a four-dimensional object, itself a unit to be synthetized from its projections.

The highest outcome of the progress of painters in handling color is shown in "Synchromy," an attempt to express by color-compositions with no definable shapes, the realities of the artist's spirit. Morgan Russell's "Synchromie Cosmique" is an example. He says of it "a spiralic plunge into space, excited and quickened by appropriate color contrasts, is designed to get rid of definite objects to intensify color rhythms, and thus emphasize the innate beauty." When one hears these songs harmonized on the melodies of light, he comes to the very spirit of beauty. He might intellectualize them and would find therein a structure very like many things already in mathematics; and he could state theorems and might thus convince the intellectual critic that they surely hold reality. But a wild rose is something more than a dihedral group of order ten, and synchromy is more than a kaleidoscopic moment. The spiralic plunge into the scarlet mockery of weakness, gray midwinter and dead dreams, violet memories, green pastures, orange conflicts of the spirit with itself, black whirlpools of struggle and failure flecked with golden sparks of illusions, out into blue depths and mysteries, through the golden city of art, to the white unattainable perfection,[14] swept along on the cosmic winds—shall we reach the ultra-violet ecstasy the spirit passionately longs for?

Color-Music: Creator of Rainbow Phantoms

We are led inevitably to the consideration of the orchestration of color just as

[14] See preface to J. G. Fletcher, "Goblins and Pagodas."

sound is organized into music. The clavilux and similar instruments for the production of mobile color, one of the newest arts, has been made possible by the development of electric lighting in all its forms. Before a performance of this organ one sits in silence, entranced by a new world, space and time have vanished, old ideas are gone. We see the birth and vanishing of creative forms in marvelous colors, almost actual spirits. It is a cosmic art, for it has flung a net over the Aurora, the only thing nature produces like it. It is very complex, for there are tints corresponding to musical tones, but of a far greater range of nuances. There are values for which music has no counterpart. There are intensities, color melodies, polyphotic effects, counterpoint. When we have many such instruments combined into modern simultaneous art we might conclude there is no art superior to this. It carries all possibilities of abstraction, all the spiritual qualities of light itself. It does not represent objective things. It is the essence of esthetic. There are no copies of nature, however lovely; no story condensed to the simplest tabloid; no suggestiveness by hinting at something unseen; no symbolism for something else. We have sublimated art with no background to distort our vision. We have the unique experience of the wondering child seeing his universe as a fresh, living, changing meadow of flowers. We witness the first act of creation under the command, "Let there be light." And there is light in many senses, for in the study of these rainbow phantoms we come to see in an unobstructed view the kind of reality the artist is setting before us, a new sort of mathematics indeed, with its very distinct and vivid spiritual fusings that take the place of material relations. Some day there will be written the great treatise on "Harmony and Counterpoint of Color-Music," an account of the structure of intoxicating beauty of the most spiritual kind. And a coming Beethoven will create symphonies surpassing anything the world has yet seen.

V. Music: Creator of Ethereal Flowers

Boom! and the deep-toned note of the big bell drifts away under the curved roof of the temple, and ripples against the golden curtain. Clang! from all the gongs, and the golden veil is rent, disclosing a "naked, rose-empurpled god, rippling with crimson-violet light."[15] The artist feels something has been born of him. These instantaneous waves of sound in a harmonic instant give a picture in tone. They are static, but they awaken echoes in the soul from both past and future. Music itself, however, is not static; it is a mobile art given to the world centuries ago when man learned how to control sounds long before he learned how to control light. Music was bound to come as the natural outlet of the eurythm in his spirit, though the first great art was dancing.

"The secret of music is the secret of all art."[16] It is called an abstract art like mobile-color. There is no subject-matter, it tells no story, there is nothing objective save a few unguessed ripples of invisible air. It passes away with the playing, can not be placed in a museum, nor hung in a salon. It shows very clearly the synthetizing power of the psyche, for it consists objectively of nothing but sequences of many simultaneous sounds, yet these are organized into a single unit. The entire composition, however much time may be necessary for its execution, is a single work of art. Then too the spirit of music, even more subtle, is not in the sounds at all, but yet is the essential part. Hence it may be called an abstract art, but that does not mean intellectually abstract. Musicians mean the opposite of sensuously concrete,

15 J. G. Fletcher.

16 Colin McAlpin, "Hermaia."

and esthetically abstract, not philosophically. Yet because of its very tenuousness it appeals to more persons than any other art. Plato says: "Music gives soul to the universe, wings to the mind, flight to the imagination, a charm to sadness, gaiety and life to everything. It is of the essence of order, and leads to all that is good, just, and beautiful, of which it is the invisible, but yet dazzling, passionate and eternal form."

Music is the expression of such profound realities as personality with its thousand fascinating varieties, persistent, free, creative and immortal, the phoenix ever rising from its ashes. These are infinite terms whose content has been declared to be nil. But in this art we find direct experience of these realities, not as concepts, constructs nor conclusions. Music represents the continuity in spirit, its fusion with other spirits, its intuition of itself as individual. It is the complete expression of pure personality. It is the expression of the ineffably divine. It is the expression of our awareness of the spiritual universe in whose ambient atmosphere we live and move and have our being. In music man expresses his appreciation and understanding of his ultimate goal. This explains the intimate mixture of music and religion, whether we find it in Brahms or in Gounod. Music is a power which lifts us on the wings of aspiration into that empyrean whose crystal air and ethereal light is beyond all reach of the transient, the phenomenal, the ceaselessly changing and vanishing. Through music we reach the world of truth which the mystic finds, "even as the waters of the infinite ocean send their waves to break among the pebbles that lie upon its shores."[17] Consider the prelude to Lohengrin. It has been said that Beethoven wrote the Ninth Symphony to exhibit the existence of God. Beethoven himself said his Sonata Appassionata was Shakespeare's "Tempest."

[17] William James.

Like all arts music has expanded and tried to get away from conventions and canons whose only source of authority is their age. It has attempted to find more freedom in new ways of expression so as to set forth profounder spiritual realities. The names of Stravinsky, Schoenberg, Varese, Casella, Falla are well known, even though they have not accomplished all they had in their souls. Back of these are Strauss, Debussy and Ravel with others. They have tried to produce sheer music, free from the usual attachments, symphonies corresponding to the synchromies of the painter, with the added dimension of time. Whatever the music of the future may be with new modes of expression we know that it will be powerful in the life of man.

VI. Dancing: Creator of Radiant Youth

Pom, pom, pom, the drum is sounding, and on the hard ground of the New Mexican village the thud of dark feet, accompanied by the chant of Indian voices, is dancing the seed down, down, down, into the ground with all the transferred energy of the Indian soul to make it grow, sprout and fruit plenteously. Some day the blue, red, yellow and white grains will give back more energy. During the whole day "Winter" and "Summer" have alternated dances increasing in vigor, becoming "an organic paean of praise of life." The powerful rhythm even gets into the blood of the spectators with its movement, vibrating color and intense spiritual fire.

The stage is dim, and the black velvet curtain at the back hangs in long folds that lead up into the top. There glides out upon the boards a piece of floating thistledown, which begins to weave patterns in the spotlight, back and forth, in graceful curves, a body as flexible as a wisp of mist.

More than the ripple of grass and waters flowing,
More than the panther's grace,
Or lily moved by winds from sunset blowing, . . .

An evanescent pattern on the sight . . .
Beauty that lives an instant to become
A sister beauty and a new delight.

Through you the past is ours,
Through you the future flowers,
Through you we find again
That birth of bliss and pain,
That thing of joy and tears and hope and laughter
That men call youth.

Dance on, translating us the mortal's guess
At Beauty and her immortality,—
Yourself your flesh-clad art and loveliness.[18]

The dance is over, the stage is dark again. Then the spirits of the aurora begin to play, formless, glowing with such color as conveys subtlety, all the intricacies of the wistful dreams of man, "the imprisoned essence of the winds, varicolored lightning, fairy forests, the laughter of spring and the golden browns of autumn"[19]—sighs, hopes, dreams, aspirations, wraiths of beauty in the making. Into the vaporous light there wind low threads of music—such music as Ravel could write for a fairy dance—and borne on the haunting strains dancers float in, drenched in color, glowing with light, and all the radiant beauty of unveiled spirit is visible, exquisite, enwrapped with poignant sound, expressed in the most perfect of all media art could use: the human body in the sway of a creative artist. Through all the music, the color, grace, shines the greatest of all reality—eternal youth. Can art surpass this in any other way?

Dancing may become again what it was originally, the expression for the religion innate in man. Here is a stage, half-way up a hill, set against the sky. The Prophetess sits brooding over the sins and the suffering of the world; below her feet the milling, toiling mob of humanity ebbs and flows, suffering, loving, hating, battling, a chaos of emotions. The Prophetess ascends to the heights invoking the higher powers. In a flash of illumination the Powers above remind her man is the child of spirit not matter. This message she conveys to the distracted masses, a little at a time, till all have joined in one great spiral praise, the dance of cosmic harmony. This is Ruth St. Denis in her new program. When will she be seen in "The Beatitudes," "Babylon Is Fallen," and "The Woman and the Dragon"? Will this be the form the church of the future will have?

Thus the dance completes the cycle of the arts, and comes back to its beginning in one of the great vortices that sweep the soul of man along the ages—the oldest of the arts, using the human body alone, the most perfect as the most difficult of media. The grand orchestral synthesis of resources of all the arts, modern dance in modern dance-compositions will give a magnificent, overwhelming, complex interpretation in art to man.

All dreams that Hope has promised Love
All Beauty he has sought in vain,
All Joy held once and lost again.[20]

For man is the gorgeous, newly emerged psyche, drying his wings for an everlasting flight through the eternity of beauty, over the ocean whose singing blue is the harmony of the spheres, following the radiant sun. The artist sees realities only!

18 George Sterling, "To a Girl Dancing."

19 Sheldon Cheney, "A Primer of Modern Art."

20 G. Sterling.

WHAT IS PHILOSOPHY?

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PHILOSOPHY is seen differently through different eyes. Some see it as good. Some see it as bad. To some it is mysterious.

The good view comes, naturally, from its appreciators; the bad and the mysterious from those who fail to understand it. The blame for these latter views rests partly upon the inherent nature of philosophy—its impenetrability to the uninitiated—partly upon those professors of philosophy who glorify themselves by appearing in a cloak of mystery or who are too impatient to lead the novice step by step, but most of all upon those impatient seekers who wish in a moment what can be had only in an hour.

The darker side of the estimation of philosophy is well worth viewing. A student informs us: "The term 'philosophy' conveys to most people a vagueness and uncertainty. The layman is ignorant of its aims and the popular impression is that it is a collection of high-flown, meaningless words and phrases on useless subjects." Such a view is not without foundation, but it is a foundation of failure. The grapes are sour to those who can not reach them.

Mysterious? "Philosophy is a mysterious subject," says C. J. Ducasse. Yet philosophy is no more mysterious than agronomy, astrophysics, ethnography, seismology or any other subject with which one is not familiar. The unknown is mysterious. And while philosophy does deal with the unknown, its mystery comes mainly from ignorance and unfamiliarity.

Philosophy is good—to those who understand it. Volumes of praise testify to its value. But praise of philosophy is no proper part of this essay. Rather the aim here is to set forth a few fundamentals. Appreciation will follow understanding.

One of the most difficult questions which a philosopher or teacher of philosophy has to answer is: "What is philosophy?" "The word," a student tells us, "is one of those elusive abstractions which, rabbit-like, always barely escapes capture and definition. It means a variety of things to a variety of persons. Each man you questioned would stop, meditate and give you another definition."

A perusal of current attempts to define philosophy would confirm this student's view. The differences between definitions offered by contemporary specialists are not merely verbal—they are real. The "basicness" of these differences will be demonstrated in a moment. First, a word about method.

No attempt will be made to define philosophy—to confine philosophy to the limits of a single sentence. What follows will be a description, not a definition. Four distinguishable components are present in philosophy. A description of all four is necessary for a complete description of philosophy, even though many definers neglect, and others deny, the importance of some of these components. What are the four components? Philosophy is a kind of *attitude,* a kind of *method,* a group of *problems* and a group of *theories.* Not all attitudes are philosophical attitudes. Not all methods are philosophical methods. Not all problems are philosophical problems. And not all theories are philosophical theories.

Philosophy as an attitude and method is emphasized by Brightman and Barrett.

Says Brightman: "Philosophy is essentially a *spirit or method* of approaching experience, *rather than a body of conclusions* about experience."[1] Rejoins Barrett: "It is *not* the specific content of *these conclusions, but the spirit and method* by which they were reached, which entitles them to be described as philosophical."[2] Ducasse apparently is willing to confine philosophy to method when he says: "Were I limited to one line for my answer to it, I should say that philosophy is general theory of criticism."[3]

Emphasis upon philosophy as problems or theories, on the other hand, appears in Leighton's definition: "Philosophy, like science, consists of *theories or insights* arrived at as a result of systematic reflection."[4] For Maritain, as for Herbert Spencer, "Philosophy is concerned with everything, is a *universal science.*"[5] To this Sellars adds: "Our subject is a *collection of sciences,* such as theory of knowledge, logic, cosmology, ethics and aesthetics, as well as a unified survey."[6] Any student of the history of philosophy will testify that problems and, especially, theories are what one seeks in philosophy.

Regardless of the varying emphases, and in spite of the genuine differences, in contemporary definitions of philosophy, philosophy can be described. It shall be described as being constituted of all four components, not of any one or two alone. Let us consider each in turn.

What is the philosophical attitude? Certainly not all attitudes are philosophical attitudes. For example, attitudes of joy, of jealousy, of despair, of fear or of intolerance are not philosophical. Persons who are at times philosophical may also have these attitudes, but when they do have them they are not philosophical. The philosophical attitude can best be characterized by nine words or phrases:

Troubled, perplexed, wondering. Philosophy begins in wonder. It begins in perplexity. It begins in curiosity. There must be a problem. An untroubled attitude is not a philosophical attitude.

Reflective. Merely being confronted with a problem does not constitute a philosophical attitude. The problem must be thought about, pondered over, and a solution attempted.

Doubting, undogmatic. He who would be philosophical must be able to entertain doubts about his beliefs. Reflection without willingness to doubt accepted beliefs can hardly be considered philosophical.

Open-minded, tolerant. One with a philosophical attitude will be not merely undogmatic about his own beliefs, but open-minded and tolerant about the beliefs of others. He will give every belief a hearing, and will not condemn without reason.

Willing to be guided by experience and reason. Since, with regard to most fundamental problems, the facts are not all in, the philosophical attitude is one which is characterized by a willingness to discard present beliefs and to accept new ones if new facts of experience demand a change. By reasoning logically about problems we often find that certain of our beliefs must be given up if others are to be held. The philosophical attitude is one which accepts the guidance of logical reasoning.

Uncertainty, suspended judgment. The philosophical attitude involves willingness to remain uncertain about any and every question concerning which the evidence is not all in. The philosopher is willing to suspend judgment as long as conclusions are not warranted.

Speculative. Believing as well as doubting characterizes the philosophical

[1] E. S. Brightman, "Introduction to Philosophy," p. 7.

[2] Clifford Barrett, "Philosophy," p. v.

[3] C. J. Ducasse, "Philosophy of Art," p. 3.

[4] J. A. Leighton, "The Field of Philosophy," second edition, p. 3.

[5] J. Maritain, "Introduction to Philosophy," p. 103.

[6] R. W. Sellars, "Principles and Problems of Philosophy," p. 3.

attitude. Even though the facts are not all in, there is always an attempt to achieve a satisfactory solution in the light of the facts that are in. Tentative solutions are sought after. It is a believing attitude, without being a dogmatic attitude, that is, it is speculative.

Persistent. Philosophy is a persistent attempt to solve problems. A momentary doubt or speculation does not make a philosopher. The philosophical attitude is an outgrowth only of a long period of reflective thinking. Philosophy is a quest for understanding which refuses to be discouraged by difficulties—is "an obstinate effort to think clearly." It is not so much intelligence, as patience, which prevents the average man from becoming philosophical.

Unemotional. The philosopher is noted for his "cool calm reflection." It is a disputed point whether any attitude can be free from emotion. At any rate, the philosophical attitude is one in which emotion is at a minimum and reason at a maximum. As philosopher, one does not love or hate, like or dislike. One simply seeks to comprehend, to understand.

What is the philosophical method? It is the method of reflection. Reflection is not peculiar to philosophy, for every science must employ it also. But most sciences, in addition, employ experimental methods. Philosophy is not averse to experiment, but its problems, for the most part, are such that they do not permit of experimentation. The philosopher, like the mathematician (the most exact scientist), usually pursues his way without a laboratory, though he is quick to scrutinise the products of the laboratories of others. Being limited, thus, to the method of reflection, the philosopher ought to become an expert in it. And indeed he is. Even the method of reflection itself has become an object of his investigation, and the result is the basic methodological science, *logic.*

Details of logical methods are out of place here. It is sufficient to mention that at bottom stands an insistence upon consistency, the principle of non-contradiction. When two assertions are contradictory, obviously, one of them must be false. Again, there is the principle of implication. When one assertion implies another, it can be validly deduced that if the first be true, the second must be true also. Upon these principles is elaborated a system of "necessary truths" about method. He who is master of these is indeed a master of thought.

It is common practice for philosophers to probe their problems in two directions, which we may call *analytic* and *synthetic.* By way of analysis, they "divide up their difficulties," in the words of Descartes, and tackle each one separately—pressing it down to its ultimate premises. So important is this procedure that C. H. Langford has ventured to say that "philosophy consists in ostentation," *i.e.*, philosophy is the clarification of concepts to their minutest detail. It is the method of Socrates, who went about humbly asking questions, seeking simply to get a clear answer. Synthesis, on the other hand, is pursuit of the whole. Parts never stand alone. They are always parts of a whole. Thus, in order to comprehend a part completely, one must comprehend its whole. He cannot understand a spoke, who has never seen a wheel.

What problems are philosophical problems? To ask "How far is it from New York to London?" is not to ask a philosophical question. But to ask "What is distance?" or "What is space?" is to ask a philosophical question.

"Do you know whether it will rain to-morrow?"—a question of no philosophical importance. But "What is knowledge?"—a question most basic in philosophical inquiry.

"Is it true that all swans are white?" This may trouble the zoologist, but not

the philosopher. But "What is truth?" Here the philosopher is deeply concerned.

"Is it a fact that Caesar is dead?" or "Is it a fact that two plus two equals four?" These are concerns of the historian and mathematician. The philosopher wants to know "What is a fact?"

"What time is it?"—not a question for philosophy. But "What is time?"—a question of great interest.

"Is the shirt you are wearing the same one which you sent to the laundry?" Philosophers ignore such questions. But "What is sameness?" The philosopher would like to know.

"Are the Niagara Falls beautiful?"—a question for sightseers. The philosopher wonders "What is beauty?"

"Is it wrong to commit bigamy in the United States?"—a problem for jurists. Philosophers inquire "What is the nature of rightness and wrongness?"

"What is your purpose in reading this essay?"—a private matter. But "What is purpose?" and "Does the world have a purpose?" Upon these the philosopher ponders long.

The above samples, pairs of related questions—the one philosophical, the other not—should reveal that philosophical questions are always general. Questions concerning particular things do not constitute philosophical problems. When a philosopher seems to be puzzling about a particular, he is really seeking a general—a most general—principle exhibited in that particular.

If we are to survey with any degree of completeness the problems included in philosophy, we shall have to go beyond mere samples and to classify them systematically. For purposes of classification, philosophical problems may be divided into two important groups: those which constitute the so-called *philosophical sciences* and those which constitute philosophy as a *comprehensive science.*

The Philosophical Sciences: Philosophy contains within its broad domain several more or less well-developed subject-matters which are properly called sciences, although they have not been received by all as sciences of full stature. Each probes a basic question, the answer to which is essential to a complete account of the world and of life. Each examines a phase of experience as distinct and as fundamental as the so-called non-philosophical sciences. What, then, are the philosophical sciences, and with what problems is each concerned?

Logic, as already noted, is the science of the methods of reflection. This is the most basic discipline in all philosophy and in all science—more basic even than mathematics, which rests upon logical foundations. What principles are presupposed in valid inferences? What fallacies commonly occur in thinking, and how may they be avoided? What deductions are possible from any given statement? And how trustworthy are inductions from any specific set of data?

Epistemology is an inquiry into the nature of knowledge and truth and certainty. Close to psychology in some of its phases, epistemology ponders the problem of the relation of knowing to that which is known. Is an idea of a mountain like a mountain? It is not like it in size; for the idea is within one's head, but the mountain is larger than the head. It is not like it in stuff, for the mountain is made of granite and soil and sand and snow; but there is little of these in the normal head. It is not like it in shape; for the mountain has three dimensions, though seen in only two, and the mountain has numerous ridges and ravines, the idea only a few. It is not like it in duration; for the mountain endures for thousands of years, the idea for the flash of a second. How, then, is knowledge like its object?

Metaphysics investigates many problems, all related to the general question "What is the nature of being?" With-

out troubling to distinguish between the subdivisions, *ontology* and *cosmology*, let us review some of the many metaphysical questions: How many kinds of being are there? How can a universe be both one and many? What are the most basic characteristics of being? What is time? What is space? What is substance? What is a relation? What is a cause? What is a fact? What is sameness? What is purpose? What is change? What is novelty? Is the world determined? Is the world purposive? Is the world progressing? Is there a God?

Axiology is the science which asks about value. What is the nature of good? What is the nature of bad? What are the kinds of value? Naïvely the child thinks the candy bar good. And later, when sated, thinks it bad. Are goodness and badness in candy bars, or in the thinking? When a baker bakes a loaf of bread, he says it is good for health. Health is good for steady work. Work is good for making money. Money is good for lots of things. But is there something that is good for nothing except itself? That is, is there something which is just good, without being good for something?

Ethics examines the right and the wrong. Popular notions identify ethics with commandments: "Thou shalt" and "Thou shalt not." But no science ever commanded or preached. As a science, ethics investigates. It wants to know how to determine when an act is right. What is obligation? What is duty? What is conscience? What is justice?

Esthetics asks two questions: "What is beauty?" and "What is art?" That these two questions, often confused, are distinct is obvious. For some beauty is beauty of nature, not of art. And to some art is ugly, not beautiful. Both of these questions demand an answer. A picture may be beautiful to one, ugly to another. Where then is beauty? In the "eye" of the beholder? On the canvas? Or somewhere else? Having settled this question, the esthetician is troubled by a greater: What are the essential characteristics of beauty? That is, what is it that all beautiful objects or experiences have in common? There is beauty in music, painting, poetry, drama, sculpture, architecture, costumes, the dance, sunsets and women. All have something in common. What is it?

Philosophy of Religion is a branch of philosophy which inquires into the nature of religion. Philosophy of religion is not religion. Rather, it is a science which seeks to understand. The nature of religion—a very important factor in every normal life—needs to be understood. It is the philosopher, mainly, who grapples with this question. There are many great religions: Christianity, Brahmanism, Buddhism, Confucianism, Taoism, Shintoism, Judaism, Mohammedanism. If all these be religions, do they have something in common? Is there an essence of religion which is to be found in all? If so, what is it?

To this array of philosophical sciences, many more might be added. *Political and social philosophy* is relatively important, but with the development of political science and sociology as separate disciplines, questions of the nature and purpose of social and political organizations is being left to them more and more. *Philosophy of education,* which seeks to understand the ultimate purpose of education, is being handled at present largely by educational specialists. *Philosophy of history,* which attempts to interpret history, not merely in terms of political, social and economic processes, but in terms of cosmic processes—what is the place of the history of man in the picture of the universe—is a field yet relatively undeveloped. Other minor problems of philosophy must not detain us here.

Philosophy as a comprehensive science. The philosophical sciences do not exhaust the problems which confront the philosopher. The best known, and perhaps most

important, problems of philosophy are still to be considered. In three ways, philosophy functions as a comprehensive science: it criticizes the sciences, it synthesizes the sciences, and it is the "mother" of the sciences.

The sciences, physics, chemistry, biology, psychology, sociology, astronomy, etc., stand in need of *criticisms*. These criticisms are of two sorts: criticisms of presuppositions and criticisms of conclusions. Each science makes presuppositions which, if examined carefully, may be found to be untenable. To philosophy falls the task of careful examination. Again, each science makes presuppositions which, when compared with the presuppositions of other sciences, may be found to contradict them. And each science eventually arrives at conclusions which, when compared to the conclusions of other sciences, may be found to contradict them. To philosophy falls the task of comparing assumptions and conclusions.

There are many *presuppositions* which scientists naturally and normally make. Some examples: Things exist in space and time. The objects of knowing are independent of their being known. Relations exist. Facts exist. True belief is possible. Things are really separate. Assumptions so obvious as these commonly pass unquestioned. But at times trouble appears because of them. The problem of examining them for the sciences becomes the concern of philosophy. Also, when different sciences make contradictory assumptions, philosophical problems arise. So long as a scientist keeps within his own field, he encounters little difficulty. Being occupied by the troubles with his own details, he usually fails to discern the implications of his assumptions for other fields of science. An illustration should make this clear:

Physicists, biologists and psychologists tend to assume that every effect must have a cause. That is, nothing can happen without being caused to happen in the way that it did happen. A body falls toward the earth instead of away from it because of gravitation. One's eyes are blue instead of yellow because of definite hereditary structures. A child is afraid of cats because he has been negatively conditioned by previous experience. For these sciences, the "law of cause and effect" holds universally.

But jurisprudence, ethics and religion, on the other hand, presuppose the contrary. That is, not everything must have happened in the way that it did. People are free to choose. They are presented with alternatives. They may select the one or the other without inevitable compulsion. Punishment is inflicted on the assumption that the law violator deliberately chose to violate. The young and the insane are exempt because they are not normal ethical beings. But the normal man is free to choose. If this were not a basic assumption, surely our laws would be written differently. Ethical codes are founded on the belief that a man can choose to follow them or not. He can do right, or he can do wrong. If it were not so, no man could be held blameworthy, and no man could be immoral. Few are the followers of Socrates who said, "No man can do wrong voluntarily."

Religious salvation is a matter of willing. "Believe and thou shalt be saved." Heaven and hell are alternatives. The sinner must choose. But *which* alternative is a matter for him alone to decide. His will is not determined. Here the "law of cause and effect" is neglected, ignored, denied.

Allowing for exceptions which occur to the alert, it is still true in general that these two contradictory assumptions are basic to different fields of explanation. Such a contradiction can not stand in a final picture of the world. No science is complete which can not fit itself into the conclusions of other sciences. To make this clear is one of the difficult tasks of philosophy.

Conclusions of sciences, like their assumptions, occasionally contradict. In

mathematics it is an accepted principle that $1+1=2$ and that $1x+1x=2x$. By reflection alone the mathematician arrived at this conclusion.

Physicists have chosen an experimental method to determine the speed of light and have concluded that approximately 186,300 miles per second is the fastest possible speed. Now if light waves are traveling in two opposite directions from a source, at what speed are they separating? At the speed of light, or at twice the speed of light?

Whenever contradictions appear, they must be resolved. When they involve one science alone, the difficulty is called scientific. When they involve more than one, the problem may be called philosophical. Thus, both with regard to assumptions and conclusions, philosophy functions as a criticizer of the sciences.

Synthesis is the second function which philosophy performs for the sciences. Each science dwells on one phase of experience. Each does its part. But where there's a part, there's a whole. To know a part only is to have a distorted view. The final goal of science should be to understand the whole—to see the picture complete. Philosophy, as a "science of sciences," as a "supreme science," as a "comprehensive science," seeks constantly to perform this function.

"The object of philosophy," says C. D. Broad, "is to take over the results of the various sciences, add to them the results of religious and ethical experiences of mankind, and then reflect upon the whole, hoping to be able to reach some general conclusions as to the nature of the universe and as to our position and prospects in it."

"Philosophy," for Whitehead, "is not one among the sciences with its own little scheme of abstractions which it works away at perfecting and improving. It is the survey of sciences, with the special object of their harmony and of their completion."[?]

[?] A. N. Whitehead, "Science and the Modern World," pp. 126–7.

Who has not heard the story of the four blind men of Burma and their visit with the elephant. Upon returning from their venture, they compared conclusions about the nature of the beast. Said one, who had felt the elephant's leg, an elephant is like a tree. Another had grasped the tail and reported an elephant to be like a rope. The trunk was traced by the third, who insisted it was much like a serpent. The other had stretched on the elephant's side and likened him to a barn. When a scientist insists that the whole universe is like the part which he investigates, he is to be compared to a Burmese blind man. We might have the separate reports of all the sciences and yet not see the whole elephant. In order to comprehend the total scheme, the function of synthesis is necessary.

As *mother of the sciences,* philosophy has had a long and interesting history. At one time there was no distinction between philosophy and science. Gradually, as the reflections upon problems became increasingly complex and as special techniques were developed, specialists limited the range of their inquiries, and sciences were born. Among the first were mechanics, mathematics and astronomy. Among the latest were psychology and sociology. The romance of the maturing of these offspring of the fecund mother must be left to the history of science. Deeper concern is felt for those yet unborn—the philosophical sciences which have not yet been granted independence.

Wonder about bearing children gives rise to speculation about philosophy's future. Will the philosophical sciences become, one day, sciences in their own right? If so, will philosophy's task be done? Will she become barren? Or will there be new conceptions now unsuspected? Optimism about her future is expressed in the following paragraph from Perry:

> As the sciences have settled area after area of his original domain, the philosopher has pushed on to the outer edge of things. The physical

frontier, we are told, has ceased to exist—so far, at any rate, as America is concerned. There is no more free land. But the passing of the intellectual frontier is not in sight. There is plenty of free land beyond the areas which religion and the sciences have fenced and cultivated, and brought under the rule of law and order. The philosopher lives on this frontier and makes crude charts of the region which lies beyond. In the nature of the case, the mass of mankind must remain in the settled communities, while the pioneers must be few and sparsely distributed. But it has always been true in America that some flavor of the frontier spirit has pervaded even the settled communities—some love of freedom, some boldness of action, some primitive sense of fair play. So it is not unreasonable to suggest that the great body of normal, sane, practical, respectable people, the people with whom philosophy is not a vocation, will, especially if they be American and have the blood of frontiersmen in their veins, nevertheless find the essential spirit of philosophy congenial. They will, perhaps, wish to make occasional excursions for themselves; but in any case, they will respect those qualities of mind that prompt other men to plunge into the deep waters and roam the trackless forests of the great intellectual adventure.[8]

By way of summary, we recall that philosophy is a group of problems. It accepts as its own both the problems of the nebulous philosophical sciences and the problems of a comprehensive science. Its comprehensive functions include, first, giving birth, then, settling quarrels, and finally, harmonizing in one house the several somewhat self-centered sciences. And "a mother's work is never done."

What theories are philosophical theories? Perhaps the simplest, if somewhat inaccurate, answer to this question is that philosophical theories are those which have been propounded by philosophers. This leaves the problem of deciding who were and who are philosophers. Such an answer may serve when we are concerned with philosophical theories of the past. Traditions have developed in the history of philosophy. We now point without question to Socrates, Plato, Aristotle, Plotinus, St. Augustine, St. Thomas, Bacon, Hobbes, Descartes, Locke, Berkeley, Hume, Spinoza, Leibnitz, Kant, Hegel, Schopenhauer, Schelling, Neitzsche, Bradley, Bosanquet, Royce and James.

But there are many others. And who shall decide which others? Further, not every theory proposed by each of these men can be considered philosophical—Berkeley's essay on tarwater, for example. Yet such an answer suffices for the novice investigating history, provided he select a competent guide.

But for contemporaries—how shall their status be decided? Dewey, Whitehead, Russell, most will agree, are philosophers. But who else? There are hundreds who deserve the name. Yet not every teacher of philosophy is a philosopher. How shall the line be drawn?

Another answer to our question is this: Solutions to philosophical problems are philosophical theories. Having determined what problems are philosophical, it becomes comparatively easy to determine what theories are philosophical. In epistemology, for example, realism, idealism, pragmatism, mysticism, scepticism and solipsism are properly classed as philosophical theories.

Still another answer has been given. Here attitude and method are deciding factors. Barrett, as previously cited, would reply: "It is not the specific content of these conclusions, but the spirit and method by which they were reached, which entitles them to be described as philosophical."

Philosophical theories are a genuine part of philosophy. Philosophical problems constitute philosophy. Philosophical method is essential to philosophy. And there can be no philosophy without the philosophical attitude. These components are major in a complete description. This is what philosophy is—to-day.

[8] R. B. Perry, "A Defense of Philosophy," pp. 55–6.

THE FIELDS OF ENVIRONMENTALISM

By Dr. RODERICK C. PEATTIE

PROFESSOR OF GEOGRAPHY, OHIO STATE UNIVERSITY

THIS paper is presented because of the distinct condemnation which Pfeifer[1] has uttered against environmentalism. Also Hartshorne[2] recently has chosen to lay emphasis so almost completely upon cultural rather than environmentalistic geographic philosophy. In this reply I shall almost immediately belie myself. After pleading against over-rigid definitions, I shall risk attack by making three limiting descriptions. A tendency towards too-great definition in any field is dangerous. It is a poor omen. Science, like art, is in a decadent stage when it becomes conventionalized. Philosophic progress can be measured by the willingness to explore. The complacent or timid stay at home. In a colony of coral polyps it is the organisms on the fringes of the reef that are best nourished. It is the frontier that gives most to history. Geography is no exception. I must give credit to those who would construct a strong core of what is called pure geography. But more leaven is to be found upon the margins. The stimulation that means progress is for those who explore perilous frontiers. In such advanced areas definitions of fields of study are merely restricting.

Having spoken against definitions, I find it, however, necessary to my thesis to differentiate between chorographers, cultural geographers and environmentalists. I hasten to add that to me these schools of effort are none of them oppositional, but that they are complementary. Moreover, the supporters of each are ordinarily regionalists. My personal reaction to geography is that it is little if not regional. No regional contrasts—no geography. Even comparative geographers must have regional concepts as a basis of their comparisons.

The chorographer is a trained observer. He records minutiae with scientific accuracy. The results of his work are fundamental. Chorographers are trained landscapists, archivists. I count myself as one among them. I value the experience. I believe every geographer should undertake chorographic studies. On the other hand, I am quick to state that chorography has its limitation. It is difficult to conceive of chorography as a philosophy. Such a technique of approach should never be thought of as an end in itself. Collecting facts leads to erudition but not necessarily to intellectuality in the philosophic sense. Robert Platt supports this idea in his recent article on British Guiana. Certainly, the chorographers were correct when they insisted that accurate recording of facts must precede generalization. On the other hand, we do not need to map every square mile of the earth, except by way of inventory. I believe the sampling of typical areas will serve our purpose. I exemplified this in a study of the Eastern Pyrenees. Again, geologists, from whom we borrowed the survey method, do not map every detail of a mountain range before theorizing upon orogeny. Also, limitations of chorography are illustrated by the prevailing unliterary character of the reports. I find them dull reading. I have been guilty of this same boring of my public.

1 Gottfried Pfeifer, "Regional Geography in the United States Since the War," American Geographical Society.

2 Richard Hartshorne, *Annals of the Association of American Geographers*, September and December, 1939.

The cultural school of geography in distinction to the environmentalistic school arises naturally from the reciprocal character of the geographic relationship. The philosophy of each school is in no way exclusive of the other. The cultural geographer concerns himself with man's adaptation of the earth to his purpose. Thus a sophisticated landscape is the result of man's choice. Rightly most geographers are cultural geographers because most of the features of modern countries are artificial. Think of a campus, the arrangement and material of the buildings and its exotic Gothic arches. I, personally, have not contributed greatly to this line of thought because I fear that in many cases, dealing as one does with such obvious tangibles, my conclusions would be patent to all. The field lacks, to me, controversial aspects except when it enters the realm of economics. By way of indicating that much excellent work is accomplished by people outside our academy, let me mention that my favorite piece of cultural geography is called "Grape Harvest." It is by Nora Waln and is found in the *Atlantic Monthly* for October, 1937.

I must now defend that Cinderella, environmentalism. Environmentalism has been sent to the corner in the ashes because of the error of her ways. I grant no scholarship has been more erroneous than that of environmentalism. As stimulating as Bodin, Montesquieu and Buckle were in their day, their generalizations were damaging to the philosophy. Even the well written dust-to-dust statement that opens Miss Semple's great book is sentimental rather than rational. Some of the environmentalists have been faulty, to say the least, in their thinking. Reputable journals have printed material that never should have gotton into print.

What is this environmentalism? It is usually thought of as the slow and not easily measurable influence of physical factors on the ways of life. Ordinarily, it is a passive influence whose result is perceptible and best measured in terms of the centuries. It involves such factors as isolation and directional contacts. It results in such conclusions as geographic limitations to cultures or the diffusion of cultures. Contrary to the popular belief it is seldom, indeed almost never, deterministic. Rather, *cultural* geography is the school of thought which leans towards determinism.

Because there is so much insistence that environmentalists are determinists, I must clarify the matter. So far geographic factors have been referred to as passive. Such influences are in the economic aspects of life only limitations. The presence of coal does not determine an industrialism. But let physical conditions alter, and it is another matter. Let aridity increase in Central Asia or the Dust Bowl, and aridity is found to determine a change in the affairs of man. You are all familiar with Ward's sketches of what happens to the farmer's family during the passage of a tornado. All catastrophic geography is deterministic. Ellsworth Huntington's theory of climatic energy in human affairs approaches a definite control. I suspect that the concept of exhausted resources forcing us to a reconsideration of our economies might furnish some with a belief in environmental determinism. I am willing to go further and say that the demands of conservation are forcing upon us a new socialism.

An evaluation of the several factors controlling cultural facts and events may be obtained from conceiving all history as existing within a cube. Let us begin our three dimensions with the lower, forward right-hand corner. The three dimensions shall represent the three factors of heredity, environment and human choice or volition. Proceeding from this corner each dimensional arrow would represent increasing importance of each

of the factors. Every fact of civilization may then be plotted in space within the cube according to the varying importance of the three factors. Most human history has, of course, a genetic predetermination. However unimportant, the environmental factor is certainly present. The human choice is all too obvious. Again, the Gothic arches of the university are a matter of human choice. If there is a determinism due to any one factor, the results must be plotted at the far corners of the cube. Such results are mathematically highly improbable. To believe in a single factor as deterministic, we must demand of our judgment that two of three variables be reduced to zero and, on the percentage basis, the third factor be rated exactly one hundred. Such conditions may happen but obviously are rare. The question of determinism is therefore hardly worthy of our attention. And by determinism I mean a dynamic and not a limiting force.

Is environmentalism of any significant service? The primary field for the environmentalist may be looked upon by the geographer as too broad for his attention. This is the field of environmentalism as opposed to genetics. There are excellent books in this field by biologists and medicos, as the recent "Environment and Growth" by Sanders. The geographer, with few exceptions, has ignored the fine philosophic opportunities to be found there. He is at times sorely needed because the biologists and medical research men are not qualified by training to evaluate geographic factors. As we maintain sub-departments of biology called genetics, we should maintain sub-departments of environmentalism.

A second field is that of the geographical factor in history. Unfortunately the English have perverted the phrase, historical geography, until it stands for merely place geography written into history. But some historians have been lucidly conscious of the geographical factor in history. Lack of support of this important philosophy of history is the geographers' fault rather than the historians'. More has been done along this line in ancient and classical history than in the later periods. I have only to mention the names of James Breasted and Ellen Churchill Semple. I can not think of any brand of geographic thought which has a greater opportunity for philosophic depth or for popular appeal. The economic historian and the realist in current affairs, usually non-geographers, have seized upon the opportunity. But again, the trained geographer is here needed and too seldom has responded.

A third, and my last, field for the environmentalist will, I am afraid, not appeal to many persons and yet is a problem of regionalism. There is interaction between the three factors of my postulated cube. Environment and heredity interact upon each other. Man's choice affects both the other factors. We can not deny then that environment affects man's choice. In short, environment affects psychology. There is a regional psychology. Obviously, the geography of mental characteristics is not of the same definitude as regional economics. But lack of definition makes a fact none the less real. That which can be defined or even proved may be of less significance than the unprovable and imponderable. After all, much cultural history and certainly a great deal of current conflict is based upon regional psychology. That there should be a geography of cultural attitudes is not startling. Philosophers, essayists, novelists, poets and artists have known it for a long time. Geographers, however conscious of it they may have been, have given the influence of physical circumstance on psychology little written support.

If philosophic writers in other disciplines and the creative arts are taking advantage of environmentalism, we

should in turn take advantage of them. Geographers will do well to read the psychologies of MacDougal, Porteus, Kuffka and Lewine. After reading Cressey on China, go to the works of Pearl Buck. Her characterization of Wang Lung and his obsession for land is grand Chinese culture. No one has demonstrated better the harmony between soil, rhythm of nature and peasant mentality than Louis Adamic in "The Native's Return." There remains yet for the geographer to surpass the relationship of depleted resources and mental depression exemplified by Archibald MacLeish in "Land of the Free." I have read one of MacLeish's manuscripts critically, and I know he prepares himself well in environmentalism.

Since we do not believe in actual inheritance of social traits, we must search for other causes for the persistence of national psychologies. The answer is that there is a cultural surge to history. Strong and often dominant factors in culture character are isolation, the soil, the climate, the sea. Indeed, the most sensitive measure of regionalism is a people's temperamental attitude towards life. We have definitely discarded the theory of racial characteristics for the more plausible culture characteristics. Celtic imagination is not inherited, it is handed down. Psychologies are not inbred; they are intrained. And the greatest discipline we receive has always had an earthly origin. Environment is like a number of finely meshed screens, selective according to the shapes of the interstices. We encounter these screens in our restlessness or as the screens change with unstable physical conditions. The story begins with the isolated culture of Egypt. It explains the sea motif in Greek history. It can not be ignored in Soviet affairs.

I am not insisting that we must all as ecologists pursue environmentalistic theories. Thinking environmentalistically means casting aside exact postulations, formulas and conclusions. It calls for imagination and a quality of scholarship which at times may seem not to be starkly rational. Yet, if it lacks statistics by which the equation may be solved, it frequently demonstrates by its logic more significant hypotheses and theories that can be demonstrated by the clearly observable. Moreover, its even partial conclusions are frequently of as wide interest and of as great philosophical consequence to the world as a whole as is the enumeration of sequence occupance.

Yet, I hold in high respect the advanced labors of the chorographer and cultural geographer. The chorographers' work is basic. Only after the cultural geographer has completed his work can the environmentalist reach his complete conclusion. But I must insist that environmentalism remains a significant pursuit of great philosophic depth. It has been so for two millenniums. In all justice, let me say, that if cultural geographers do not wish to recognize environmentalism as having a place above the salt, environmentalism welcomes and needs the efforts of its younger brother. Geneticist, environmentalist, cultural geographer and psychologist should unitedly put their shoulders to the wheel. I might well have labeled this paper, which is little more than an exposition of a personal choice of philosophy, "With Malice towards None."

BOOKS ON SCIENCE FOR LAYMEN

THE TRUTH ABOUT THE CUCKOO[1]

NEARLY two decades ago, Mr. Edgar P. Chance published his first book on the European cuckoo, *Cuculus canorus*, and simultaneously exhibited the motion picture record of his observations, both entitled "The Cuckoo's Secret." It is no exaggeration to say that no single study of any particular species of bird ever caused as much interest and heated controversy as did this one. Chance was able to reveal so convincingly that so much of what had passed for knowledge was in reality only unwarranted assumption or ill-founded tradition that many die-hards, finding themselves unable to adjust their thoughts to the new evidence, clamored loudly against the cause of their discomfort. From the start it was obvious that all the direct positive evidence was on Chance's side, and the years have witnessed a more and more complete acceptance of his conclusions. The main points that Chance established were: (1) the cuckoo lays her eggs directly into the nest of the victim and not, as previously stated, on the ground, subsequently placing them in the nest with her bill; (2) the female cuckoo has a definite territory to which she adheres throughout the season; (3) each female cuckoo lays a constant type of egg and is decidedly specific in her parasitism, *i.e.*, uses only nests of a single kind of bird as a host; (4) by destroying the nests of the favorite host species in sequence, so that only one nest was available at a time, it was possible to force the cuckoo to lay in a given nest and therefore to witness the process. Since Chance's first book in 1922, a number of other observers have used his methods and fully confirmed his observations.

In his new book, here under review, Chance repeats all that was said in his earlier one and gives many additional data from subsequent observation of the same individual cuckoos and of other ones as well. In addition, he discusses such topics as accidental fosterers (species rarely parasitized), the adherence to fosterers (host-specificity), the behavior of fosterers when subject to a cuckoo's attention; the young cuckoo and, especially, its habit of ejecting other young or eggs from the nest, and the question of mating and pairing and the moot subject of territory and territorial dominance in the cuckoo. He produces a considerable body of evidence suggesting that the cuckoo may pair as do most birds and not be guilty of the promiscuous excesses literature has attributed to it. Chance even hints that pairing may be for life—but for this there are no proofs.

The final topic discussed is the matter of the variation in cuckoos' eggs and the evolution of adaptive similarity in the egg of the parasite to that of its favorite host. As Chance says, ". . . If one examines an extensive range of cuckoos' eggs, together with those of the fosterers with which they have been found, one can not help observing how often the eggs of the parasite tend to resemble those of the fosterers. . . . To put this another way, let us picture say three hundred cuckoos' eggs mixed up at random which have been genuinely taken as to one hundred each from nests of pied wagtail, meadow pipit and reed warbler. I am suggesting that the experienced oologist would, with more accuracy than error, sort out these eggs and assign them to their correct foster species. Surely this shows that evolution in coloration has been and is going on? . . . Of course, if it is argued that similarity can occur infinitely often by coincidence, then the whole case for 'adaptation' or 'evolution' in cuckoos' eggs falls to the

[1] *The Truth about the Cuckoo.* Edgar Chance. xvi + 207 pp. 1940. Scribner's Sons.

ground, but I share the view that the percentage of cases of striking resemblance between cuckoos' eggs and those of their fosterers is too great to be mere coincidence.'' This leads to the contention that the species, *Cuculus canorus*, is composed of gentes, each gens normally parasitizing a particular species of fosterer (the number of common hosts being not very large, the number of gentes would be equally moderate, all cases of rare victims being considered as accidental in one way or another) and that matings take place within the same gens. The genetics of the cuckoo are, of course, very imperfectly understood, but in an appendix to Chance's book, Professor R. C. Punnett has added a most interesting and suggestive chapter on the genetical aspect of the cuckoo. The value of this chapter will become apparent in the work it may stimulate on this fascinating subject.

The reviewer has a special and very deep interest in the problems touched upon in this book, because it so closely parallels his own work on the cowbirds. He is continually impressed by the close agreement he finds in interpretations and results between his own experience and Edgar Chance's, especially when taking into account the very different birds each has worked with. If Chance's work needed any indirect corroboration and support, the data on the cowbirds would give it.

HERBERT FRIEDMANN

MAMMALS OF AMERICA[1]

A CAREFUL reading of this book will convince the reader that the author has made good use of original literature sources, that he is thoroughly conversant with the subject-matter and that he has carefully considered the presentation of pertinent facts. It is a book that every mammalogist, naturalist and sportsman will want to read. Representative types of the mammal families of North America, from Panama to the Arctic barren lands, are chosen to illustrate the particular topic under discussion, but no attempt is made to give detailed accounts of each species. The first two chapters are devoted to a discussion of the ancestry and classification of mammals.

Prior to the publication of "American Mammals," reference works available to the interested reader were mainly state descriptive lists, taxonomic treatises of genera, economic reports and game management accounts. From all these and many other sources data were drawn in preparing the chapters on adaptations, food, storage, reproduction and early life, homes, hibernation, migration, populations, behavior and distribution. The concluding chapters are arranged in such a way as to give a general account of the economic relations of mammals. Those in this category are classed as useful mammals, injurious mammals, game, fur-bearing and predatory mammals.

In the chapter on the characters of mammals, the reader gets a good insight into the function and use of teeth, hair specialization, pelage coloration, antler and horn structure, body temperature, normal actions of skin glands and secondary sexual characters. Especially instructive to the lay reader is the chapter dealing with the external and internal modifications of mammals for swimming, burrowing and climbing, and the factors that make existence possible in polar regions and in desert areas. Since Rubner's body surface law is the premise around which much of the section on Arctic mammals is organized, attention should be directed to the somewhat different conclusions reached by Benedict (1936, Carnegie Inst. Washington Publ. 474, pp. 282–286). In all the chapters the emphasis lies distinctly on the ecological approach as a means for interpreting the various phases of mammalian biology. One of the best features of this

[1] *American Mammals.* W. J. Hamilton, Jr. Illustrated. xii + 434 pp. 1939. $3.75. McGraw-Hill.

book is the direct citation of consulted source materials.

REMINGTON KELLOGG

THE PATIENT'S RESPONSIBILITY[1]

OPTIMISM is a potent force, but it is not omnipotent. Carried to extreme it is prone to become self-destructive. Science must be constantly conscious of the dangers of wishful thinking. We must not promise more than we know is feasible. The promise implied in the title[1] of a recent book for the lay reader on problems of health preservation is misleading. Health and longevity are not to be had for the mere asking; fairies and genii no longer work miracles upon request. Neither can the physician maintain health without earnest effort on the part of the patient. And even then, there are many to whom health and life are denied. To be sure, modern medical science now has far more than ever before to offer the person seeking sound advice as to how to maintain health and prolong his years. The *potentialities* of personal preventive medicine are immense, but their realization depends largely upon the conscientiousness of the individual patient.

Mankind reveals a curious perversity in declining to exert himself in prophylaxis on his own behalf. The causation of several of the significant and increasingly menacing disorders of middle and later life is frequently associated with indulgence and excesses. Thus, preventive management often involves irksome restrictions and prolonged personal efforts. All too often the dislike for such continuous limitations leads to their neglect; the physician is then blamed for the failure of the régime. Few, indeed, are those individuals who do not welcome an opportunity to pass responsibility to another. It is, therefore, doubly dangerous to imply that mere asking for health suffices. Pampering paternalism has already wrought havoc with the sense of responsibility of our citizens.

Throughout the book Dr. Steincrohn maintains a strongly optimistic tone. Such encouragement is desirable and should bring many well people to their physicians. This is the first and vital step in personal health maintenance.

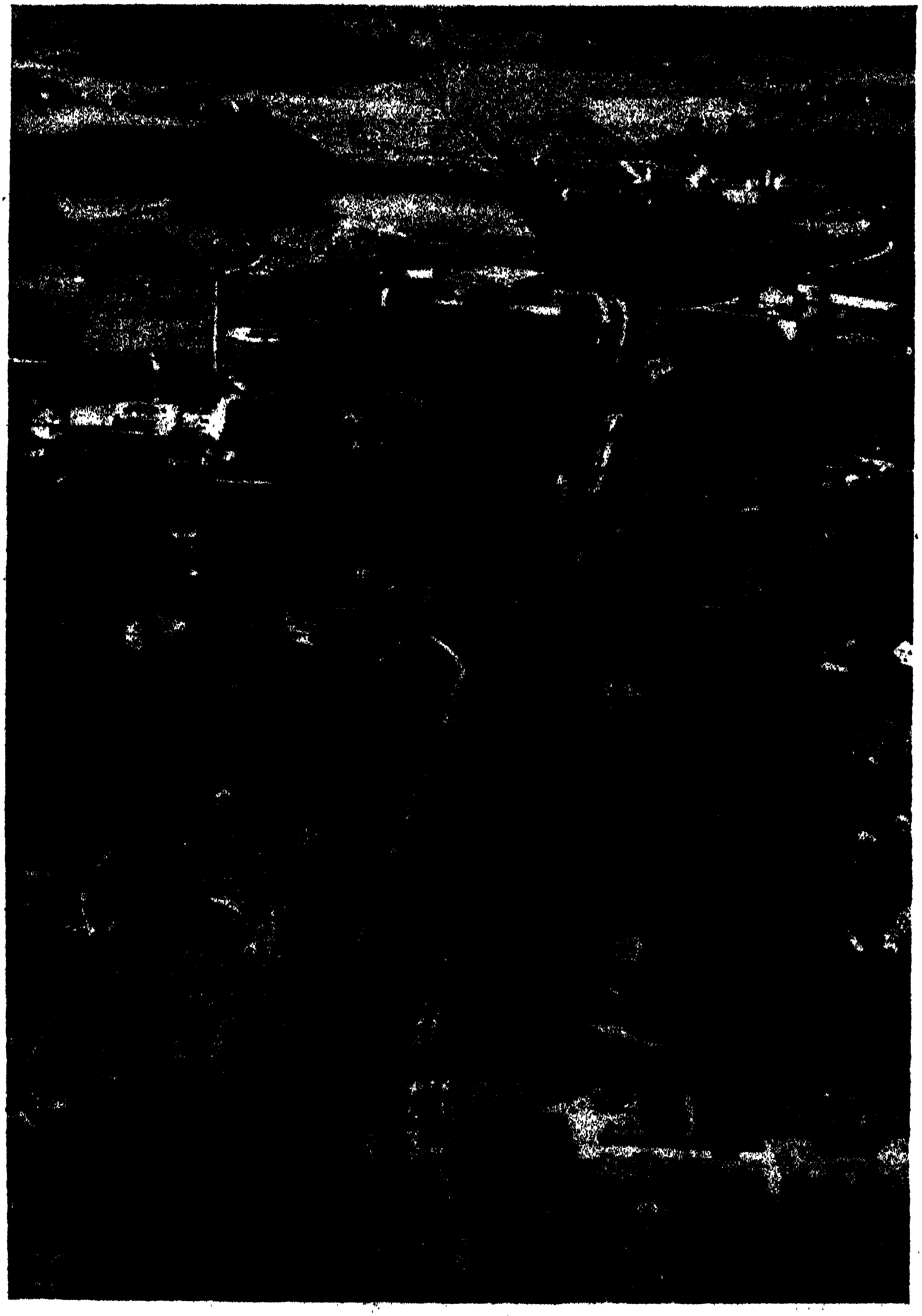
This message can not be over-emphasized. But there is just a little too much stress upon what the doctor does and too little clarification of the patient's own responsibility to himself. Ambrose Paré, the father of French surgery in the sixteenth century, was fond of saying, "I dressed his wounds and God healed him." To-day's version of the relative rôle played by the physician might read: "The doctor assists the body to do its own repairing." For example, we may prescribe medication for the correction of an anemia, but it is the body which must manufacture the blood cells.

Information for the layman on health evaluation, heart disease, cancer, diabetes, pneumonia and similar problems is clearly presented. The statements are sound. Very little effort is made, however, in explaining the mechanisms underlying disease and the basic reasons for therapeutic procedures. It has been the reviewer's experience that intelligent and effective cooperation is obtained best when the patient understands *why* he or she should do things. The style is light, with many personal narrative sketches used to illustrate the author's points.

In contrast with the many widely inaccurate books of health, hygiene and medicine intended for the layman, this is a very sound contribution and fits well in the "Popular Health Series" of the publishers. It is not, however, an outstanding or profoundly significant volume.

EDWARD J. STIEGLITZ

[1] *More Years for the Asking.* Peter J. Steincrohn. 218 pp. $2.00. 1940. D. Appleton-Century Company, Inc.



AERIAL VIEW OF THE CAMPUS OF THE UNIVERSITY OF NEW HAMPSHIRE

MEETING PLACE OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN JUNE. IN LEFT FOREGROUND IS A GROUP OF DORMITORIES, CONSISTING OF HETZEL HALL, FAIRCHILD HALL AND THE COMMONS. BEYOND THEM IS THE HAMILTON SMITH LIBRARY AND BEYOND IT, NEAR THE FLAG-POLE, IS THOMPSON HALL, THE ADMINISTRATION BUILDING. IN THE DISTANCE, AT THE BEND IN THE STREET, IS THE FIELD HOUSE, WHICH, WITH SEATING CAPACITY OF 3,500, MAY BE USED FOR MEETINGS.

THE PROGRESS OF SCIENCE

SCIENCE AND VACATION AT DURHAM, N. H.

FROM June 23 to June 28 the American Association for the Advancement of Science will combine business with pleasure in holding a meeting at Durham, New Hampshire, in connection with the celebration of the seventy-fifth anniversary of the founding of the State University. Immediately preceding the meeting of the association the university will hold a Congress of Science and Humanities as a part of the celebration.

The meeting of the association will be a pleasure to those who participate in it because on its thirty-five programs there will be many reports of new adventures in science. It will be a pleasure to pass a few days in the tranquil atmosphere of a university town. It will be a pleasure to draw apart briefly from the strife of the day and take a long look at the nature of the physical and biological worlds and at the problems of man. It will be a pleasure to visit the sea, the lakes and the mountains of perhaps the most restful and delightful vacation land in our country.

Although the association will hold a meeting from September 22 to September 27 at the University of Chicago in connection with the fiftieth anniversary of its founding, a varied and interesting program will be presented at the Durham meeting. It will range from the rare atmosphere of abstract mathematics to the racial origins of the inhabitants of present New England. The meteorologists will consider questions pertaining to the atmosphere above and the geologists to problems of the earth beneath our feet. The programs of the botanists and the geologists will consist largely of field trips. Somewhat envious members of other sections and societies may attempt to tease their botanical and geological friends about calling pleasure trips science, but the latter can make the rejoinder that Pope would have said, if he had written on the subject, that the proper study of botany is plants and of geology is the earth, and few would have challenged the statement.

Other sections and societies will visit laboratories of various kinds, experiment stations, gardens, forests, etc. The Section on Social and Economic Sciences will devote three days to discussing social and economic problems of New England. Questions of the production of food will be considered in the programs of the horticulturists and agronomists, the preservation and use of forests by the foresters, and the protection of human health by the Section on the Medical Sciences. Long ago Dr. L. O. Howard, then permanent secretary of the association, said that the greatest war on the earth is that between human beings and insects. That this has become an all-out war in dead earnest is proved by a symposium in which the entomologists will present coldly explicit directions for killing insect enemies—the young and old, both while resting in their homes and while at their regular business—by the use of the most deadly poisons the chemists can produce.

As states go, New Hampshire is not great in area or population, but it has a long and honorable history and its people have always been noted for their granite integrity. What is now New Hampshire was first seen by white men when Martin Prang visited its coast in 1603. Two years later Champlain discovered the Isles of Shoals off its coast. Captain John Smith visited it in 1614 and wrote enthusiastically of its attractions. John Mason, who received a land grant from King James I, in 1622, is known as the founder of New Hampshire. The first indisputable settlement in New Hampshire was by David Thompson, in 1623, at Little Harbor (now Rye). Originally a part of Massachusetts, New Hampshire did not become a separate province until 1679.

At the outbreak of the American Revolution New Hampshire had about 80,000

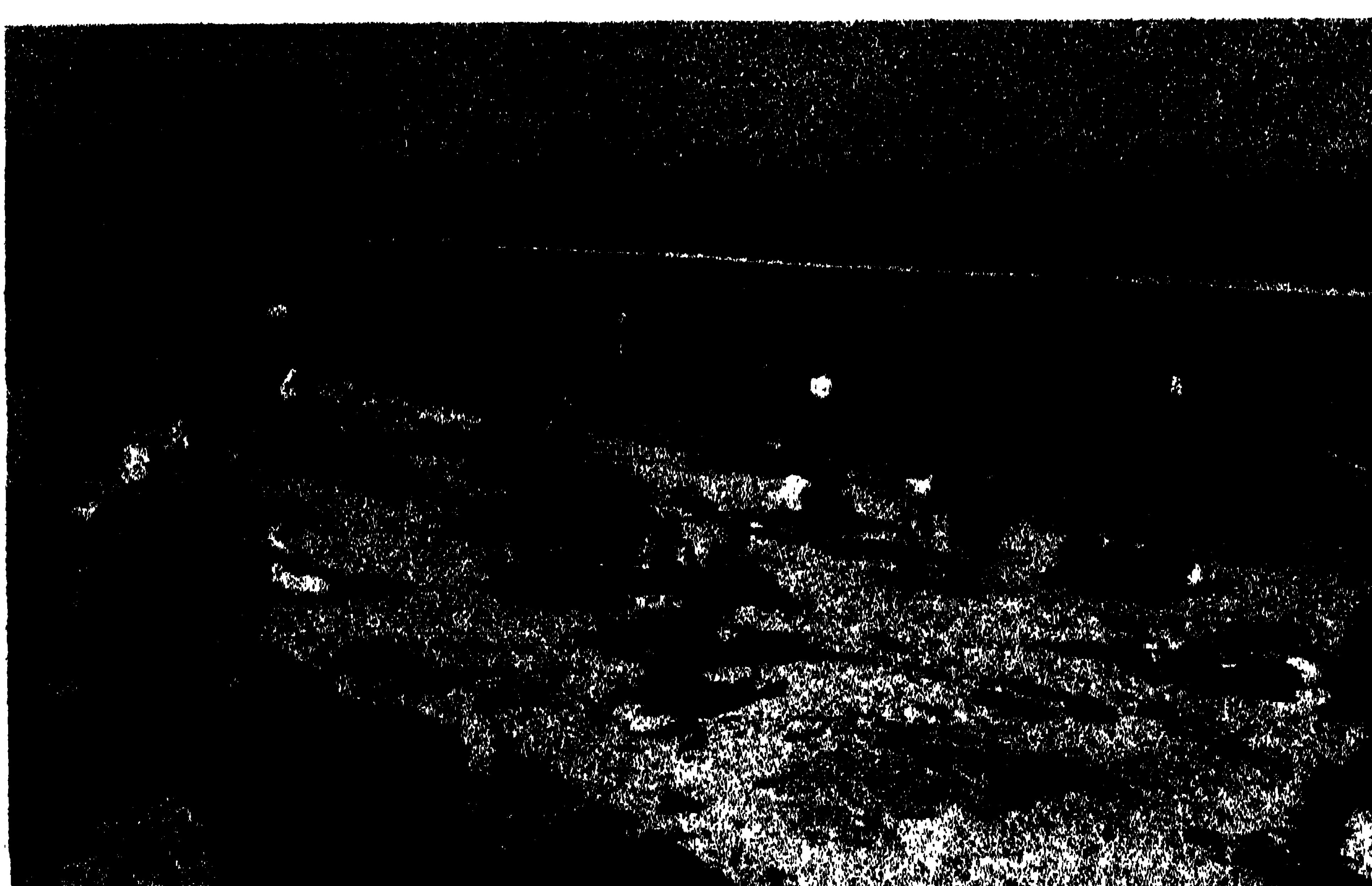
inhabitants, most of whom ardently desired to become separate from Great Britain. In fact, on June 15, 1776, two weeks before the Declaration of Independence, its Assembly voted for separation from the mother country. It was, however, the ninth state to ratify the Federal Constitution; the vote of its Assembly in 1788 gave the two-thirds of the thirteen original states necessary to make the Constitution effective.

New Hampshire was a part of Massachusetts when, in 1647, it passed a law requiring every town having fifty householders to maintain a school for teaching reading and writing, and every town having one hundred householders or more to maintain a grammar school. It has preserved to an exceptional degree the fine qualities of the neighborhood school, and one might still often say with Whittier,

> Still sits the school house by the road,
> A ragged beggar sunning,
> And round it still the sumacs grow
> And blackberry vines are running.

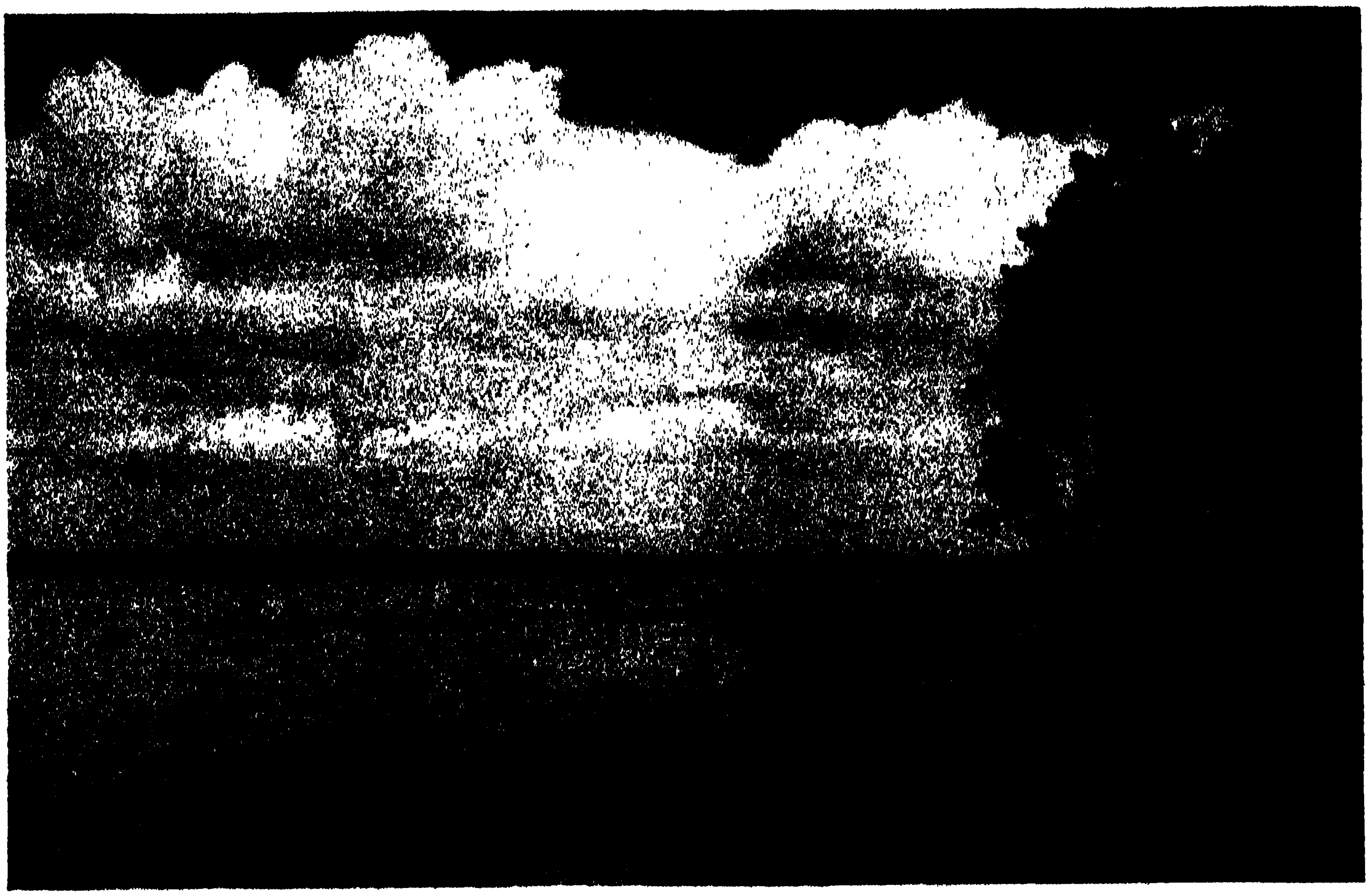
The little red school house on the hill lacked the lavish equipment and the athletic teams of modern public schools, but it opened somewhat the windows to life and lore and instilled deeply the fundamentals of human character. No one can certainly say at present which type of education in the long run will be the better.

New Hampshire, however, has kept in tune with the progress of higher education. Dartmouth College first opened its doors in 1769 and for more than 170 years has occupied an honorable, and in some respects an almost unique, place in college education. In 1856, Benjamin Thompson, a farmer of Durham, left his entire estate to the people of New Hampshire to establish a college of agriculture on the land he had owned. The University of New Hampshire, beginning in 1866 as a department of Dartmouth College, was removed to Durham in 1891. It now consists of the College of Agriculture, the College of Liberal Arts, the



HAMPTON BEACH, ONE OF THE MANY RESORTS NEAR DURHAM

SCENIC ATTRACTIONS NEAR DURHAM VARY FROM BEACHES, SUCH AS THIS 20 MILES DISTANT, TO THE WHITE MOUNTAINS AND LAKE WINNEPESAUKEE, WHICH ARE ONLY A FEW HOURS' DRIVE AWAY.



GREAT BAY FROM WEEK'S POINT, IN DURHAM TOWNSHIP
THIS INLET ON OYSTER RIVER, AT THE HEAD OF THE TIDEWATER, IS ABOUT THREE MILES FROM THE CAMPUS OF THE UNIVERSITY.

College of Technology, with their numerous departments, and its Graduate School. It has a faculty of nearly 200 of the grade of instructor and higher and more than 2,000 regularly enrolled students. In its summer school this year, beginning on June 30 and closing on August 8, courses will be given in more than 60 subjects, including all those usually found in college courses. In addition there will be held the fourth annual Institute of Public Affairs, a Writers' Conference, a Guidance Institute, an Elementary Education Conference, a Library Institute and an Office Workers' Institute.

Durham is in a region rich with memories of great leaders in learning and literature of an earlier day. In this area Whittier, Hawthorne, Longfellow, Emerson, Thoreau, Webster, Thaxter and Aldrich lived and worked, and there are found shrines in their honor. The university is only a few miles from ocean beaches and within a half day's drive of hundreds of beautiful lakes of the central part of the state. Lake Winnepesaukee, twenty miles long and from one to eight miles wide, is noted for its 274 green islands. To the north are the mountains culminating in Mount Washington in the Presidential Range with an altitude of 6,293 feet. Following the scientific meeting at Durham from June 23 to June 28, many of the scientists and their families will journey northward for pleasure to the lakes and the mountains, to silence and to solitude—no! not to solitude, for as Byron has written,

To sit on rocks, to muse o'er flood and fell,
To slowly trace the forest's shady scene,
Where things that own not man's dominion dwell,
And mortal foot hath ne'er or rarely been;
To climb the trackless mountain all unseen
With the wild flock that never needs a fold;
Alone o'er steeps and falls to lean;
This is not solitude; 'tis but to hold
Converse with Nature's charms and view her
  stores unrolled.

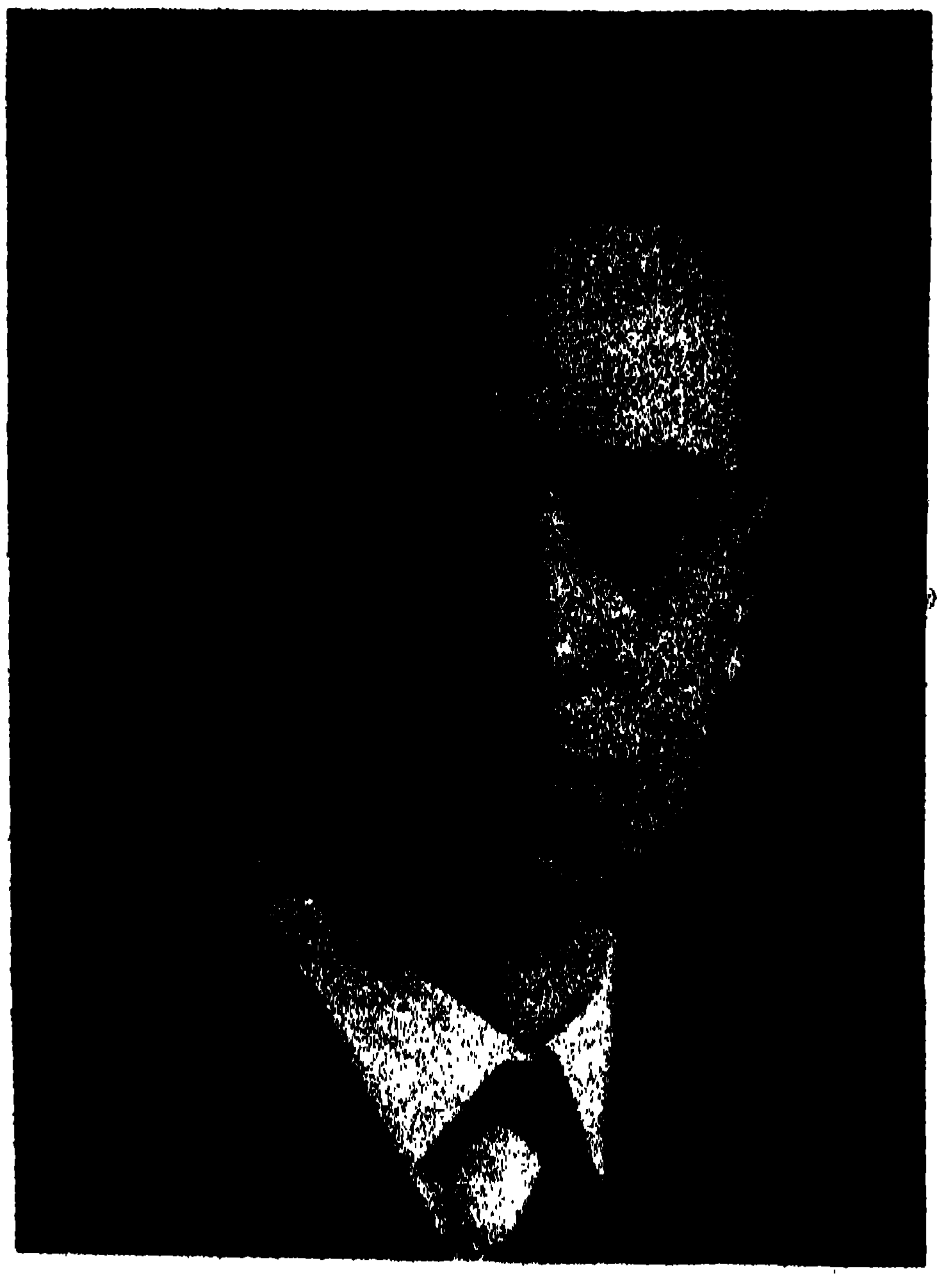
F. R. MOULTON

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE seventy-eighth annual meeting of the National Academy of Sciences was held on April 28, 29 and 30, 1941, at the Academy building on Constitution Avenue, Washington, D. C. One hundred and thirty-three members and one foreign associate attended the meeting. At the scientific sessions thirty-two papers and two biographical memoirs were presented; of these, twenty-one papers were given by members. The distribution of the papers among the sciences was: mathematics, 1; astronomy, 3; physics, 5; chemistry, 2; geology, 5; botany, 5; zoology, 6; physiology, 1; biochemistry, 1; anthropology, 1; psychology, 2; oceanography, 1. In presenting his paper each speaker sought to emphasize the general nature of his investigation and to limit technical details to essential data, so that the purport of the work might be more readily understood by scientists outside his special field of research. As a result the papers were unusually interesting and were freely discussed. The average attendance at the scientific sessions was 300.

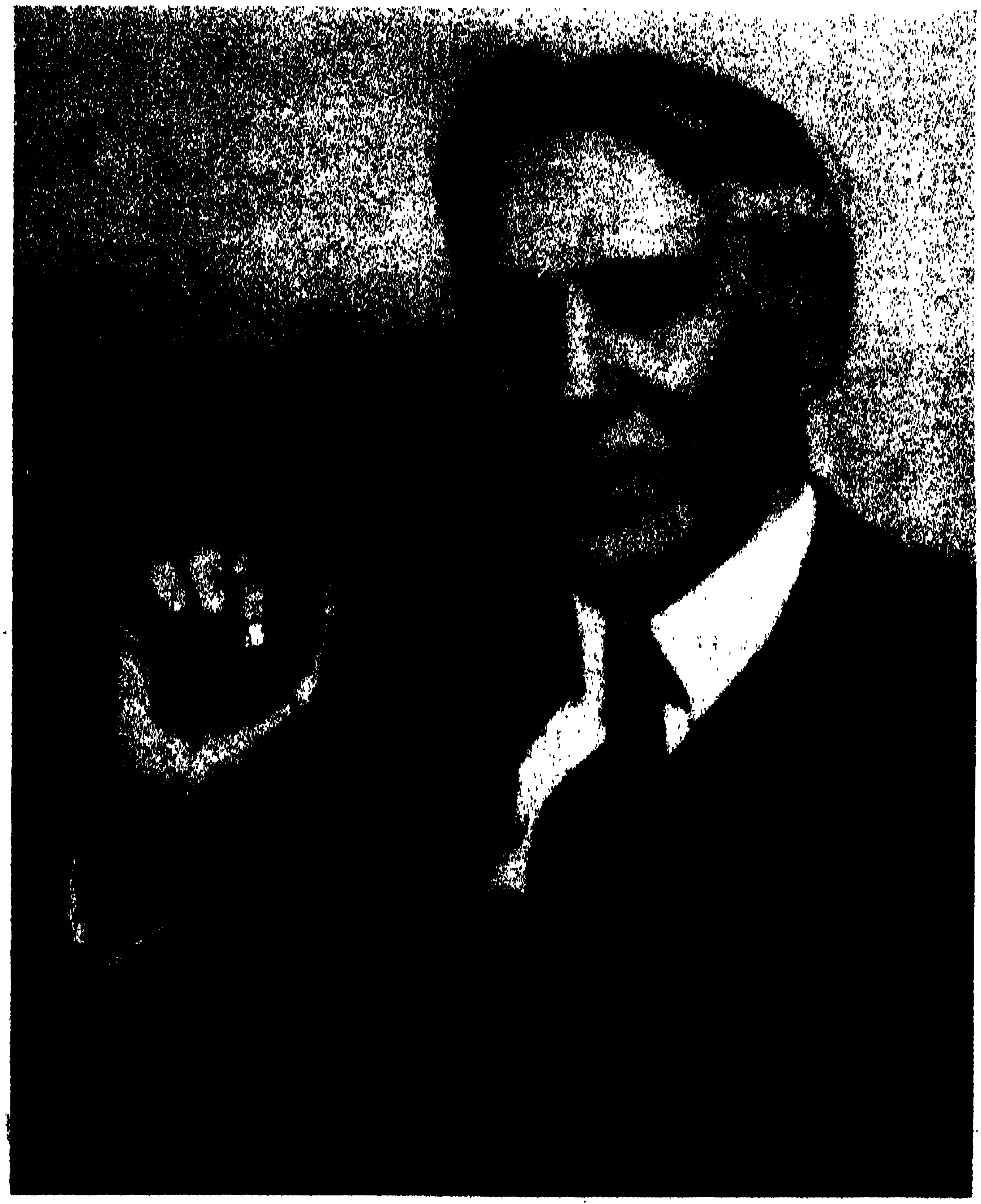
On Monday evening the public lecture was given by Drs. R. A. Millikan, H. Victor Neher and W. H. Pickering, of the California Institute of Technology, on "Testing in India a theory of the origin of cosmic rays" to an appreciative audience of 350. The lecture was followed by the showing of still and motion colored pictures taken by Dr. Neher in India and on the journey to and from India.

At the annual dinner the president of the Academy, Dr. Frank B. Jewett, discussed briefly the many problems faced by the Academy in connection with requests by the Government for advice and noted the progress that has been made in solving a number of these problems. He referred also to the steps that have been taken to establish the proposed National Science Fund. A committee of the Academy under the chairmanship of Dr. A. F. Blakeslee has been working



DR. T. Y. THOMAS
PROFESSOR OF MATHEMATICS, UNIVERSITY OF CALIFORNIA, LOS ANGELES.

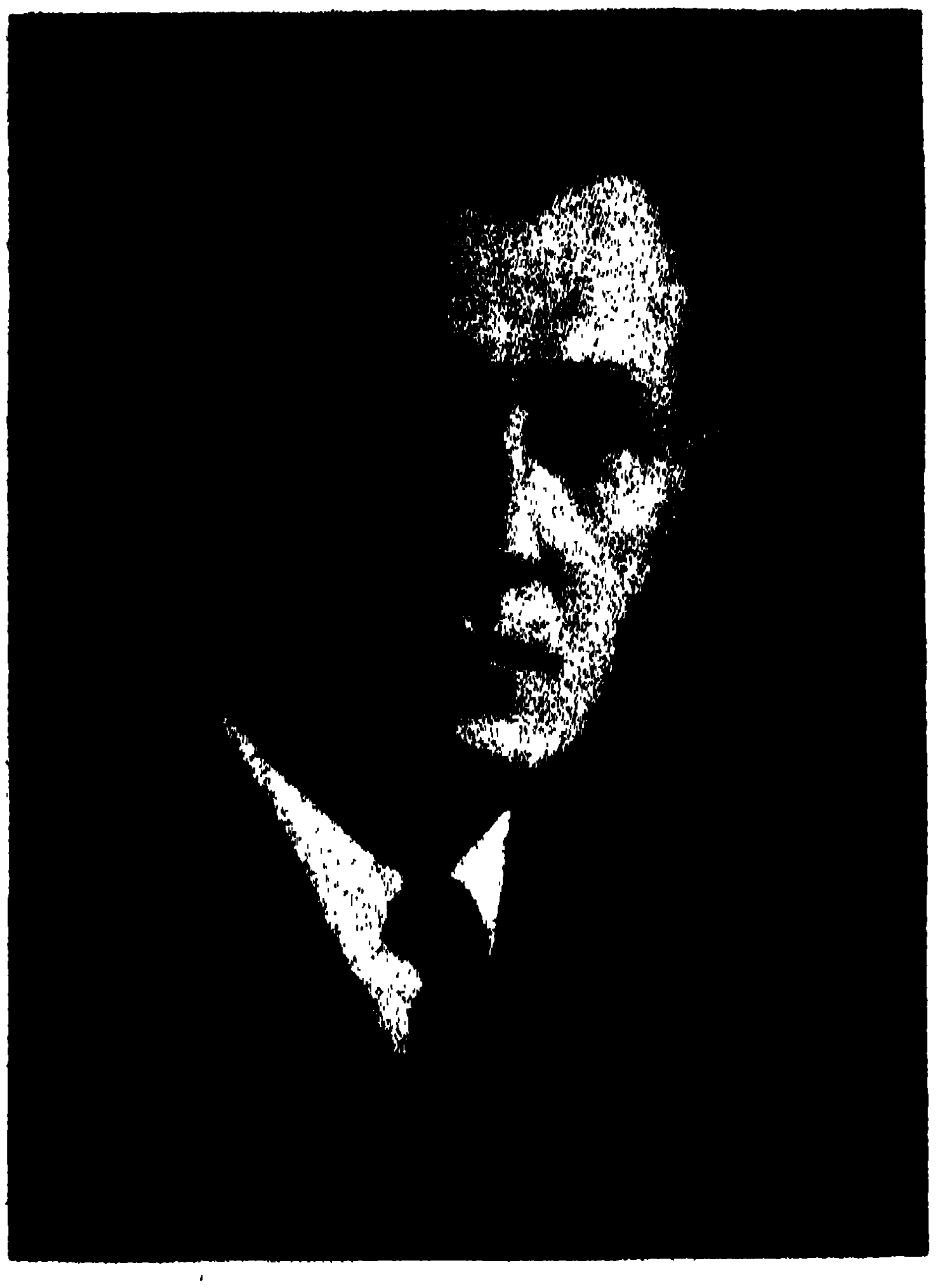
DR. ARTHUR S. KING
SUPERINTENDENT OF THE PHYSICAL LABORATORY, MOUNT WILSON OBSERVATORY, PASADENA.



DR. ROBERT WILLIAMS WOOD
RESEARCH PROFESSOR OF EXPERIMENTAL PHYSICS AT THE JOHNS HOPKINS UNIVERSITY, WHO WAS AWARDED THE HENRY DRAPER MEDAL.

on this proposal for several years; at the business meeting of the Academy the committee submitted a proposed constitution for the Fund together with recommendations for its administration. The constitution was adopted by the Academy. The object of the National Science Fund, as stated in its constitution, "shall be the promotion of human welfare through the advancement of science." Under the sponsorship of the National Academy of Sciences, the National Science Fund may receive bequests, donations, grants and other gifts to be administered by a Board of Directors appointed by the Council of the Academy. The Academy is the official scientific adviser to the Government and is qualified to evaluate the needs of science and to assure wise use of funds provided for research in science. To administer the National Science Fund the Council of the Academy appointed a Board of Directors consisting of 12 non-Academy members, and 17 Academy members; in addition, the President and Treasurer of the Academy, the Chairman of the National Research Council, and the President of the American Association for the Advancement of Science serve as *ex officio* members.

Organized as an agency of the Na-



DR. CHARLES C. LAURITSEN
PROFESSOR OF PHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY.

DR. J. R. OPPENHEIMER
PROFESSOR OF PHYSICS, UNIVERSITY OF CALIFORNIA, BERKELEY.

tional Academy of Sciences, the National Science Fund is a permanent mechanism which affords donors, who may desire to devote funds to the welfare of mankind through research in science, assurance that wise administration will safeguard the entrusted funds and disburse them in support of effective original work in science.

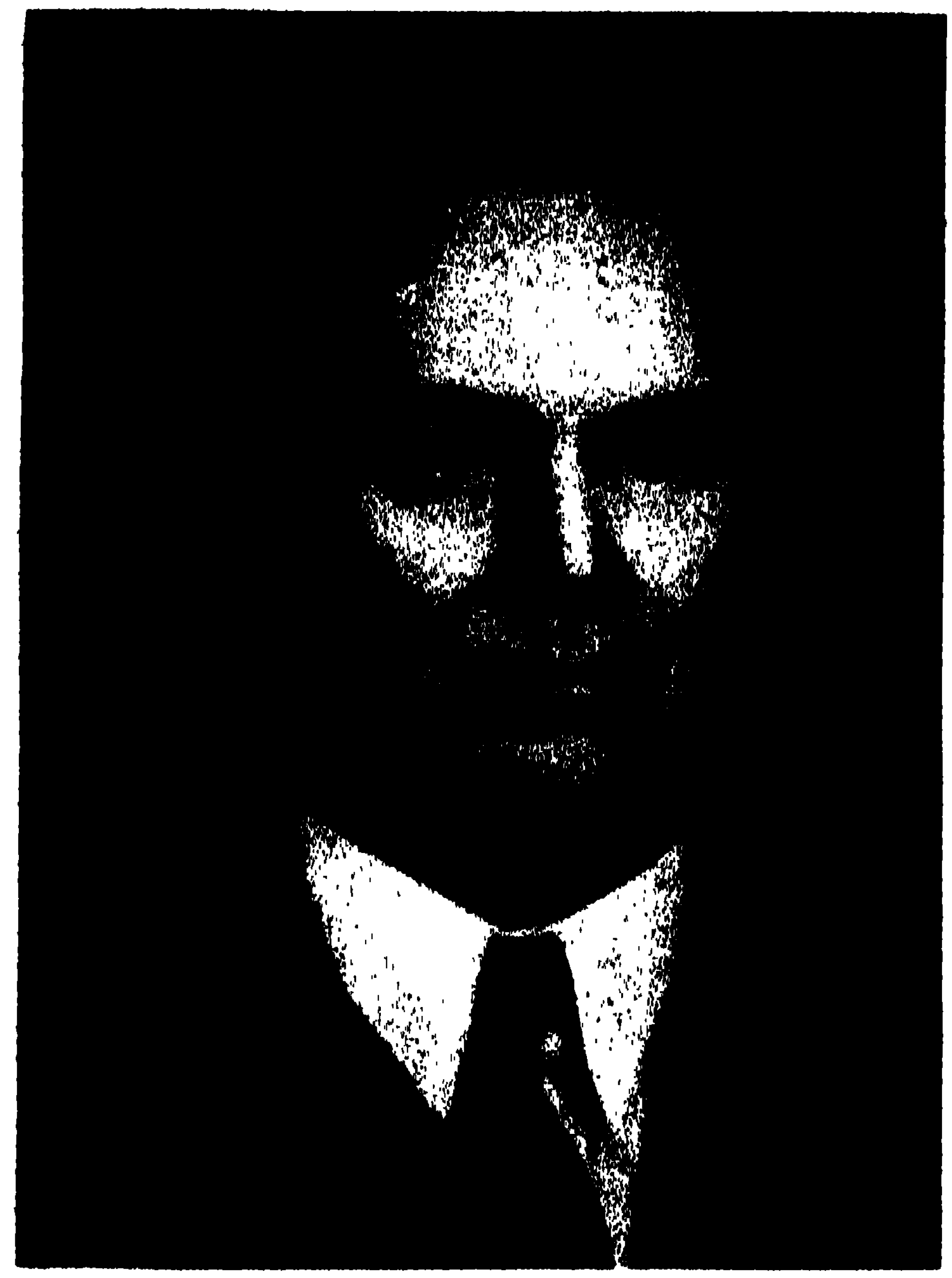
The Henry Draper Medal was awarded to Robert Williams Wood, research professor in experimental physics at the Johns Hopkins University, in recogni-

DR. W. E. BACHMANN
PROFESSOR OF ORGANIC CHEMISTRY, UNIVERSITY OF MICHIGAN.

tion of his contributions to astronomical physics; more especially his pioneer work upon resonance spectra, his use of color filters in astronomical photography and his development of methods for concentrating to a high degree the light from diffraction gratings in desired orders and regions of the spectrum. Such gratings not only are of great value in solar and laboratory spectroscopy, but have made possible the use of higher dispersion than has hitherto been employed in

the study of stellar spectra and the extension of observations into the far ultraviolet. Dr. Wood's experiments with objective grating replicas have also led to results of great promise in the photography of spectra of faint stars. In his presentation speech Dr. Otto Struve of Yerkes Observatory emphasized the remarkable advances which Dr. Wood has made in the ruling of diffraction gratings. Through selection and shaping of the point of his ruling diamond Dr. Wood has succeeded in throwing as much as one half of the incident light into a chosen order of the spectrum. He was the first to achieve excellent results in ruling gratings on films of aluminum evaporated on glass. As a result a Wood grating with high concentration of light is one of the most effective instruments of research in stellar spectroscopy. It has made possible the analysis of the spectra of the brighter stars on a large scale, has opened up the almost unex-

DR. JOSEPH SLEPIAN
RESEARCH ENGINEER, WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.



DR. L. F. SMALL
HEAD CHEMIST, NATIONAL INSTITUTE OF HEALTH.

DR. W. M. STANLEY
BIOCHEMIST, ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, PRINCETON.

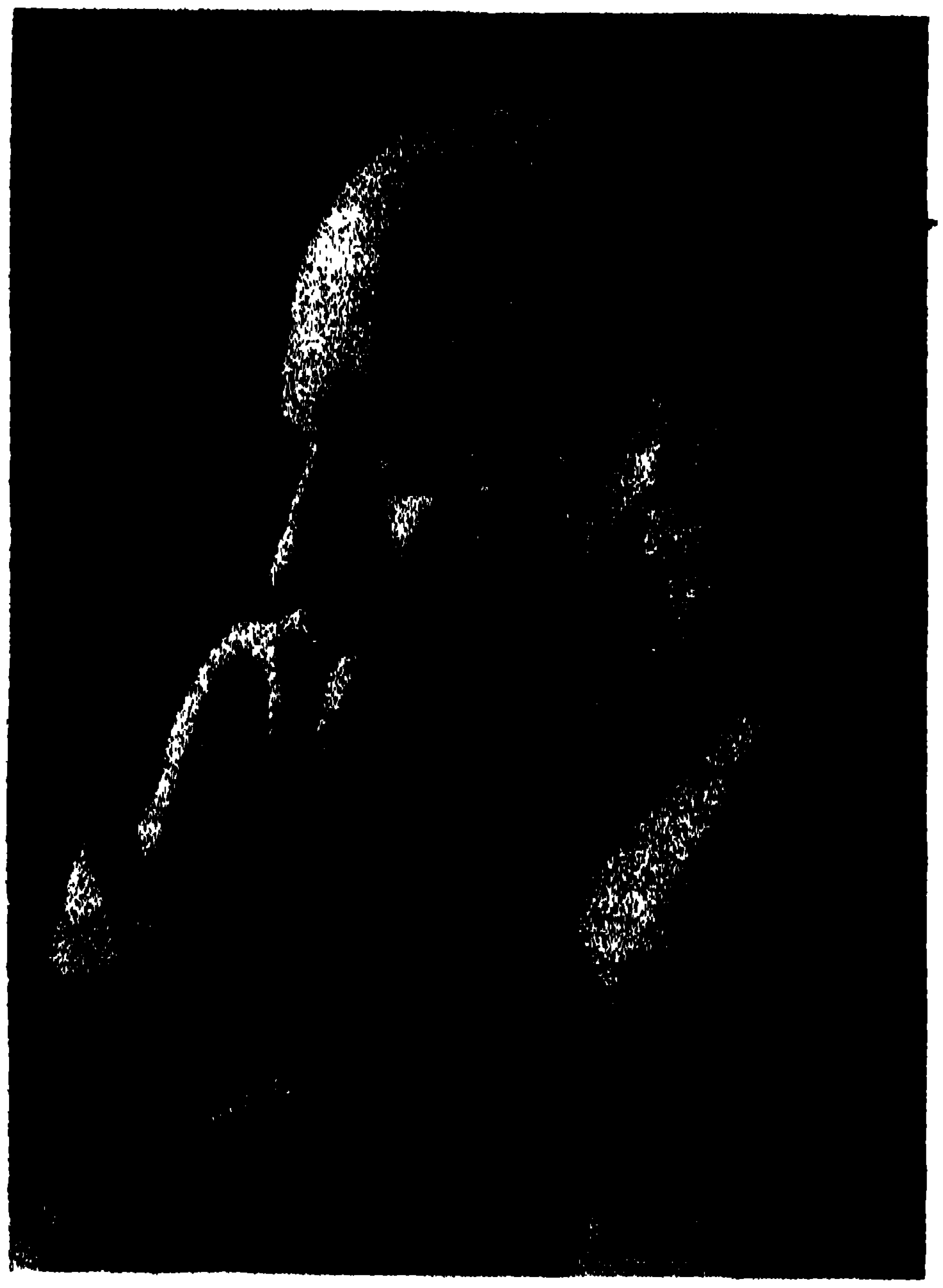
DR. KARL SAX
PROFESSOR OF BOTANY, HARVARD UNIVERSITY.

DR. GEORGE B. WISLOCKI
PROFESSOR OF ANATOMY, HARVARD MEDICAL SCHOOL.

DR. J. T. PATTERSON
PROFESSOR OF ZOOLOGY, UNIVERSITY OF TEXAS.

DR. RENE JULES DUBOS
ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH.

DR. EVARTS A. GRAHAM
PROFESSOR OF SURGERY, SCHOOL OF MEDICINE, WASHINGTON UNIVERSITY, ST. LOUIS.



DR. GEORGE GAYLORD SIMPSON
VERTEBRATE PALEONTOLOGIST, AMERICAN MUSEUM OF NATURAL HISTORY.

plored ultraviolet region of stellar spectra, and has already led to discoveries of interest regarding the constitution of the gases in interstellar space.

On Monday afternoon 75 Academy members and guests visited the National Gallery of Art which was erected through the generosity of the late Andrew W. Mellon and was opened to the public only a few weeks ago. Special guides showed the visitors through the gallery and commented upon the various collections of paintings and works of art which were well exhibited and were greatly admired. The architectural effects and beauty of the building itself attracted attention and impressed the group profoundly. The short visit was extremely interesting and was appreciated by the visitors.

At its business meeting on Wednesday, April 30, the Academy elected the following officers and members:

Vice-President
Dr. Isaiah Bowman, president of the Johns Hopkins University, Baltimore, Md.

New Members of the Council of the Academy
S. A. Mitchell, Leander McCormick Observatory, University of Virginia, Charlottesville, Va.
E. B. Fred, professor of bacteriology, University of Wisconsin, Madison, Wis.

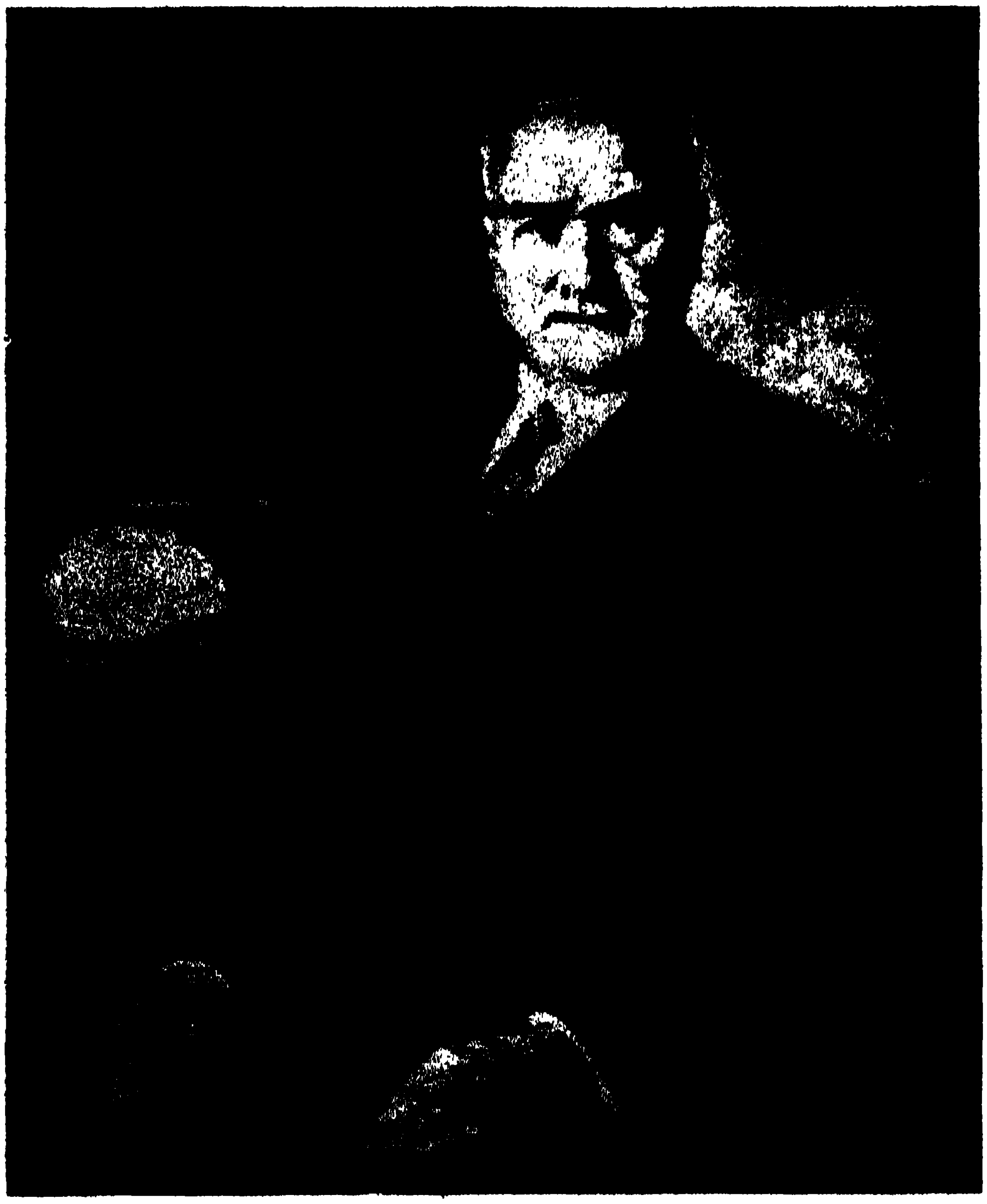
New Foreign Associates
Edgar Douglas Adrian, professor of physiology and fellow of Trinity College, Cambridge University, Cambridge, England.
Archibald Vivian Hill, Foulerton research professor and secretary of the Royal Society, London, England.
Sir Arthur Keith, Buckston Browne Farm, Downe, Kent, England.

Fifteen men, whose portraits are here reproduced with the exception of Dr. Alfred L. Loomis of the Loomis Laboratories, Tuxedo Park, N. J., were elected to membership in the Academy.

The present membership of the Academy is 319 with a membership limit of 350. There are 5 members emeriti. The number of foreign associates is 42 with a limit of 50.

The autumn meeting of the Academy will be held this year on October 13, 14 and 15 at the University of Wisconsin, Madison, Wisconsin.

F. E. Wright,
Home Secretary



DR. EUGENE DUBOIS, 1858–1940

It has been learned that Dr. Eugene Dubois, famous for his discovery, in 1891, of the skullcap of the Java ape-man, known as *Pithecanthropus erectus*, recently died at his home in Holland at the age of 82 years.

No finds relating to human pre-history have received more attention and publicity than those attributed to the Pithecanthropus, and none deserved more. Nor are the discussions yet ended. The remains were discovered between 1890 and 1897 in Java, by or under the direction of Eugene Dubois.

As a young physician Dr. Dubois was appointed to the service in Java as a result of his own efforts. He was already an accomplished anatomist, paleontologist and student of human ancestry, and he went with the object of searching for possible human ancestors in the East Indies. From 1887 he served as a "Health-Officer" in the military organization of the Colonies, but a considerable part of his time was devoted to a search of the caves in Sumatra and the collection of fossils.

In 1889 Dubois came to Java, and in April of that year he was delegated by the Colonial government, at his own desire, "to extend his studies to the tertiary and diluvial fauna of Java." From then on until the middle of 1895, the government Mining Bulletin carried quarterly a report by Dubois or others on the progress of his work, and it is in these reports that the original accounts of his fortunate discoveries are recorded.

The first note of importance is found in the report for the first quarter of 1890.

Dr. Dubois announces that he had discovered, on November 24, 1890, in the so-called Kendeng deposits of the watershed of the Bengawan river, a human fossil, consisting of a fragment of a lower jaw.

The first report by Dubois on the finds relating more directly to the Pithecanthropus appears in the third quarter of 1891. Speaking of the work near Trinil he says: "The most remarkable find however was a molar tooth (the upper third permanent molar of the right side) of a chimpanzee."

In his report for the fourth quarter of 1891, Dubois announces the discovery of the skullcap, gives the first notes and measurements on it, and attempts its classification. He says: "The Pleistocene fauna of Java, which in September of this year was augmented by a molar of a chimpanzee, was much further enriched a month later. Close to the spot in the left bank of the river where the molar appeared, there was unearthed a fine skullcap which, with even less doubt than the molar, may be attributed to the genus *Anthropopithecus troglodytes.* That both the specimens come from a great manlike ape, is at once clear."

The next note of much interest by Dubois is found in his report for the third quarter of 1892. He here announces the discovery of the femur, and gives the form represented by the finds its first specific name. The femur was discovered, he states, at the same level as the skullcap and the tooth, but 15 meters (nearly 50 ft.) further upstream; and it is plain to him that the three specimens, the tooth, skullcap and femur, belong to the same individual, probably a female of advanced age. "Through each of the three recovered skeletal parts, and especially by the thighbone, the *Anthropopithecus erectus* Eug. Dubois approaches man more closely than does any other anthropoid."

With the season of 1893 the excavations at Trinil came to an end; and towards the end of the second quarter of 1895, Dubois himself departed for Europe.

In 1894 Dubois' first important report on the Trinil remains appears under the title "*Pithecanthropus erectus,*" eine menschenähnliche Uebergangsform aus Java." In this he characterizes the new form as follows: Order: Primates. New family: Pithecanthropidae.

In the same original, able and painstaking memoir, Dr. Dubois gives his principal measurements of the skull and corresponding measurements of four chimpanzees and two gibbons.

All the above showed conclusively to Dubois that the form could not be ascribed to the *Simiidae;* at the same time, numerous characteristics of the skull, those of the teeth, and some features even of the femur, indicate that the form cannot be classed with those of the *Hominidae.* It is an intermediary form which necessitates its classification as a new genus, the *Pithecanthropus,* and a new family, the *Pithecanthropidae. Pithecanthropus erectus* is a transitional form which must have existed between man and the anthropoids; "it is the precursor of man."

Dubois' reports on the Java finds, and above all the specimens themselves after he brought them to Holland, attracted naturally the liveliest attention of the scientific world. A number of prominent anthropologists, paleontologists, and anatomists, such as Manouvrier, Marsh, Flower, Virchow, Smith Woodward, Sir William Turner, Schwalbe and others, were given the privilege of seeing the specimens; and on September 15–21, 1895, the originals were exhibited to all before the Third International Zoological Congress at Leyden, where they received great attention and much discussion.

Dubois' discovery was universally acknowledged as one of great importance; but his views were soon combatted. The case presented two main problems. The first was the question of whether the several parts, *i.e.*, the skull,

the two teeth and the femur, belonged to the same individual or at least to the same form; the other, that of the identification of this form.

But all this is not the pivotal essential of the find, and diminishes in no wise its high interest and value, both of which are universally acknowledged, particularly since the endocranial cast has become available. Neither should the student allow himself to be confused by the seeming flood of discrepancies of opinion on the remains. The differences are often more apparent than real, and even where real they by no means discredit the find, but are only so many attempts, under all the great limitations of our present collections and knowledge, to reach a true conclusion.

The Trinil skull alone is sufficient to establish the presence in what is now Java, somewhere during the early Quaternary, and possibly earlier, of a class of beings that so resembled the anthropoid apes, on one hand, and came so far in the direction of man in the other, that if they were to be named today we could hardly find a more appropriate name for them than "Pithecanthropus."

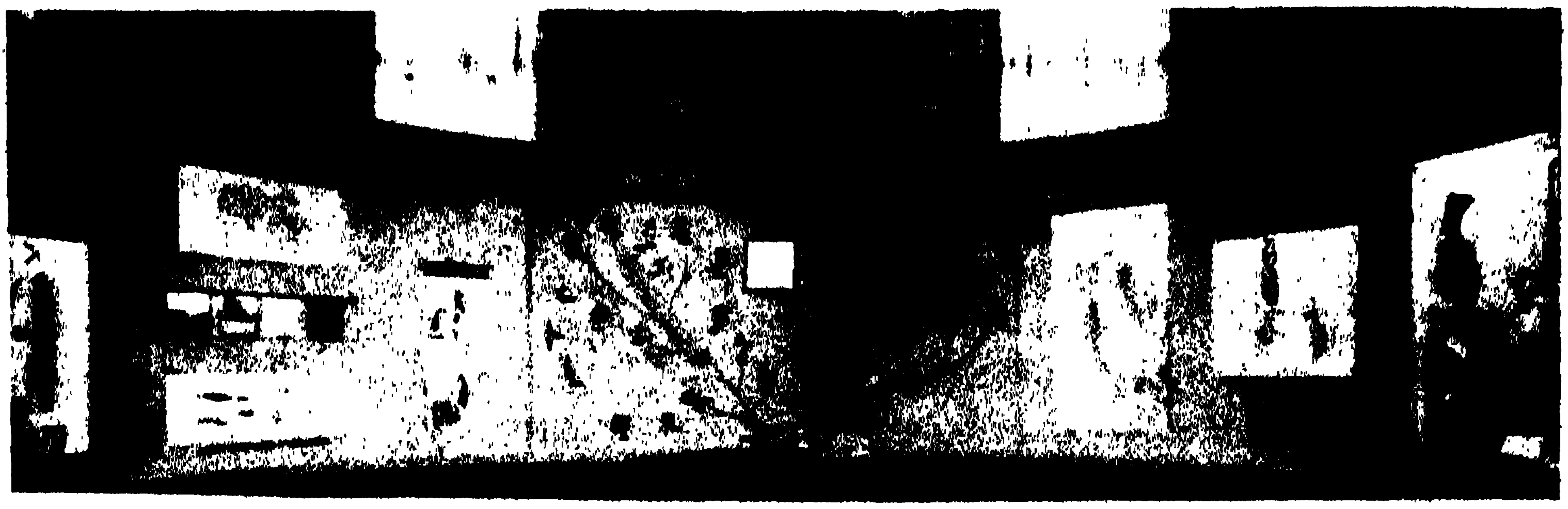
In recent years a number of additional specimens that may be attributed to the Pithecanthropus were found in the same region of Java. These are not yet fully described, but do not change the main conclusions of Dubois.

ALEŠ HRDLIČKA
U. S. NATIONAL MUSEUM

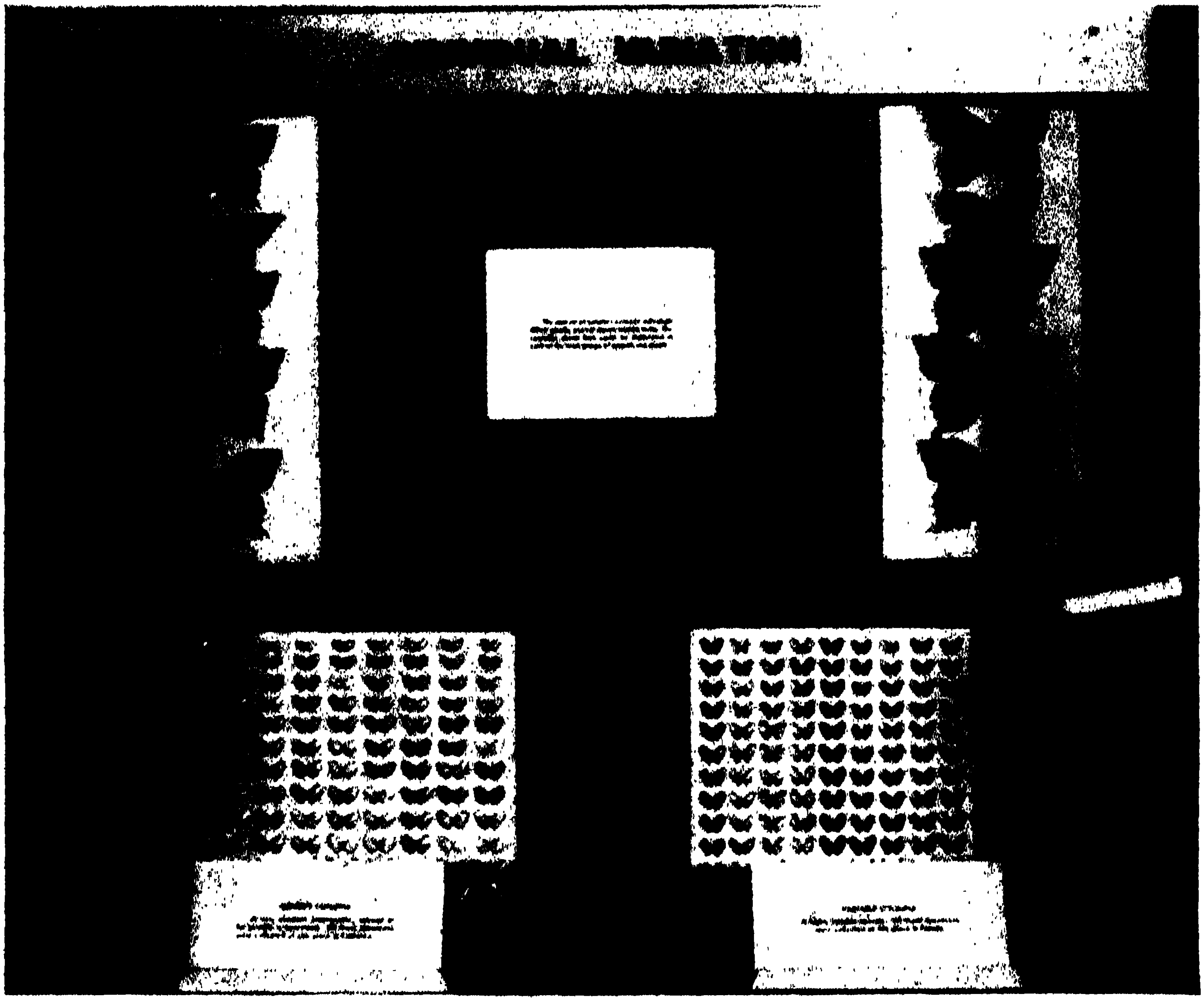
THE BIOLOGY ALCOVE OF THE SMITHSONIAN'S NEW "INDEX EXHIBIT"

THE whole field of the biological sciences is too vast for any one institution to cover. Like other research organizations, the Smithsonian has had to restrict its own labors to a small section of it and has remained faithful to the old descriptive aspects of biology, where it has been one of the most productive institutions in the classical fields of taxonomy and biogeography, leaving to newer laboratories, unencumbered with the care and responsibility of great museum collections, the more recent experimental approaches to the science. The biology alcove in the Smithsonian's new "Index Exhibit" accordingly has for its central theme "the forms of life." Here, on a hypothetical diagrammatic "tree," are painted the main groups of animal and plant life, arranged to show their supposed relationships.

Flanking this are exhibits illustrating the work involved in "description and classification" on the one side and "variation and distribution" on the other. In the former, the theme is developed



THE BIOLOGY ALCOVE IN THE SMITHSONIAN "INDEX EXHIBIT"
THE CENTER CHART IS A DIAGRAM OF THE FORMS OF LIFE. THE LEFT PANEL DEMONSTRATES CLASSIFICATION AND DESCRIPTION, THE RIGHT ONE PRESENTS VARIATION AND DISTRIBUTION.



INDIVIDUAL VARIATION

AN EXHIBIT TO SHOW SPECIFIC PHASES OF BIOLOGICAL WORK. VARIATIONS IN THE SAME SPECIES ARE EXEMPLIFIED IN THIS CASE BY SPECIMENS OF BUTTERFLIES AND SHELLS.

around the basic work, the first main step, that of collecting the materials for the specialists to study. In the upper center is a map of the world, showing all the places where Smithsonian biologists have explored and collected in the past ten years. This map is enlivened by a series of colored transparencies showing field parties at work in various parts of the world. Under this is a recessed case of "recently received material of special interest," containing at present a series of Siamese fresh water fishes, showing remarkable adaptive features and habits. On either side of the expedition map is a vertical recessed case—one with the title, "Collecting Expeditions Add New Species to Knowledge," and the other, "Collecting Expeditions Add New Facts About Known Species." In the former are shown a few selected specimens of new species discovered as a result of Smithsonian work, the total number of which is estimated to be over one hundred thousand. In the other case are illustrated groups of animals and plants being monographed at the present time.

The exhibits dealing with "variation and distribution" comprise three recessed cases. The central one is devoted to the matter of the great range of individual variation in nature—some species being very variable and others quite constant. The examples used at present are mollusks and butterflies. The case to the left of this one demonstrates geograph-

ical variation and the phenomenon of geographical subspecific groups—the song sparrow being used as the illustration. The right-hand case explains biogeography and shows on two colored hemispheres the main biological regions of the world and illustrates by means of specimens the peculiarities of one of these faunal areas, in this case, the Australian region.

HERBERT FRIEDMANN
SMITHSONIAN INSTITUTION

PHYSICISTS IN NATIONAL DEFENSE

IN his report to the Governing Board of the American Institute of Physics, Dr. Henry Barton estimated that one out of every four physicists in the United States is working on problems of national defense. The estimated number is 1,400 out of a total 4,100 physicists who are members of at least one national professional society in physics.

A recent survey of more than 130 universities indicates that, of their total staff of 1,100 professors and instructors of physics, over 100 have recently been called away from their campuses for official defense research projects. At least another 200 have been named consultants or assigned full- or part-time defense tasks at their home institutions. Some 50 graduate students of physics have dropped their studies to accept defense assignments.

In addition, there is approximately 300 physicists in the technical services of the army, navy, air corps and other government departments, mostly full time, and of these at least 250 are at work on problems intimately concerned with national defense. It is estimated that 800 of the 2,500 trained physicists employed in industry are at work on problems related to national defense, and the demands of defense agencies and industries for physicists is greater than can be met.

In industry it is estimated that 2,500 trained physicists are employed, many of them in the research laboratories of large corporations. On the basis of reports received at the institute office, at least 800 of these have gone onto new work programs in line with the needs of national defense. Indeed, if all work designed to improve or speed the production of defense materials and products be counted, the number is greater than 800.

Not only is the supply of physicists being strained, but the output of new physicists is being curtailed. The men who have been called from universities for defense research are often those best fitted to train new research physicists. However, their remaining colleagues are assuming increased teaching loads, to keep up the standards of training offered to students.

Unfortunately, the careers of many students are about to be disrupted by the draft. Most of them are unmarried and of draft age. Unless something can be done to keep these much needed students in the graduate schools, the number of men receiving advanced training in physics will drop to less than half of the recent average of 130 per year. What the country needs is to multiply this figure rather than to cut it. Since a thorough training in physics requires three or four years of graduate study, it is nearly impossible to increase the annual increment of good new physicists. Therefore, every effort should be made at least to keep it up.

W. H.

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NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS